FINAL RPORT FOR RESEARCH AGREEMENT
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"Forest Fragmentation, Vulnerability and
Habitat Selection by Elk in Chamberlain Creek"
THE UNIVERSITY OF MONTANA
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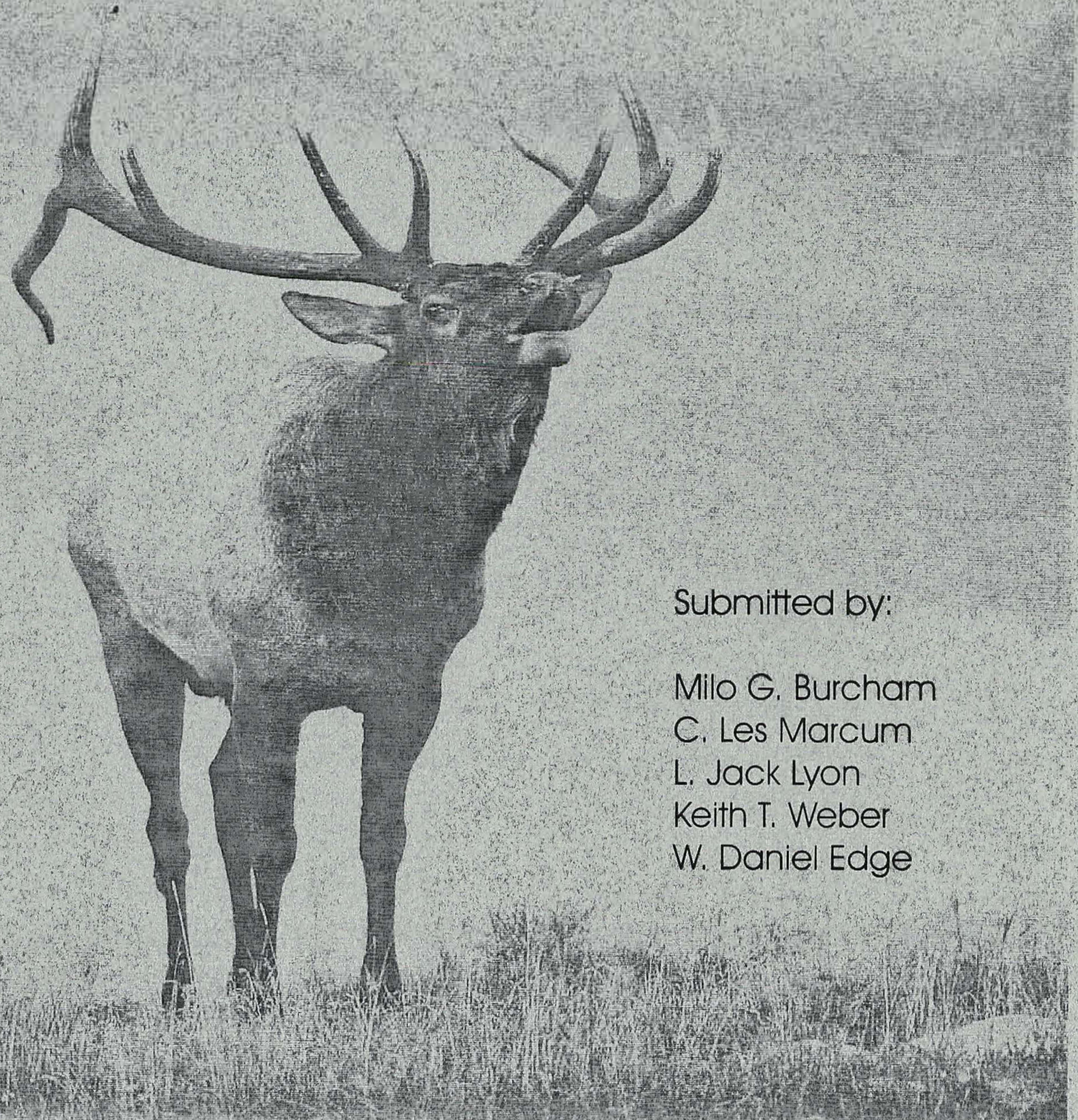
Final Report:
Chamberlain Creek Elk Studies
1977-1983 and 1993-1996

School of Forestry
University of Montana
June 1998



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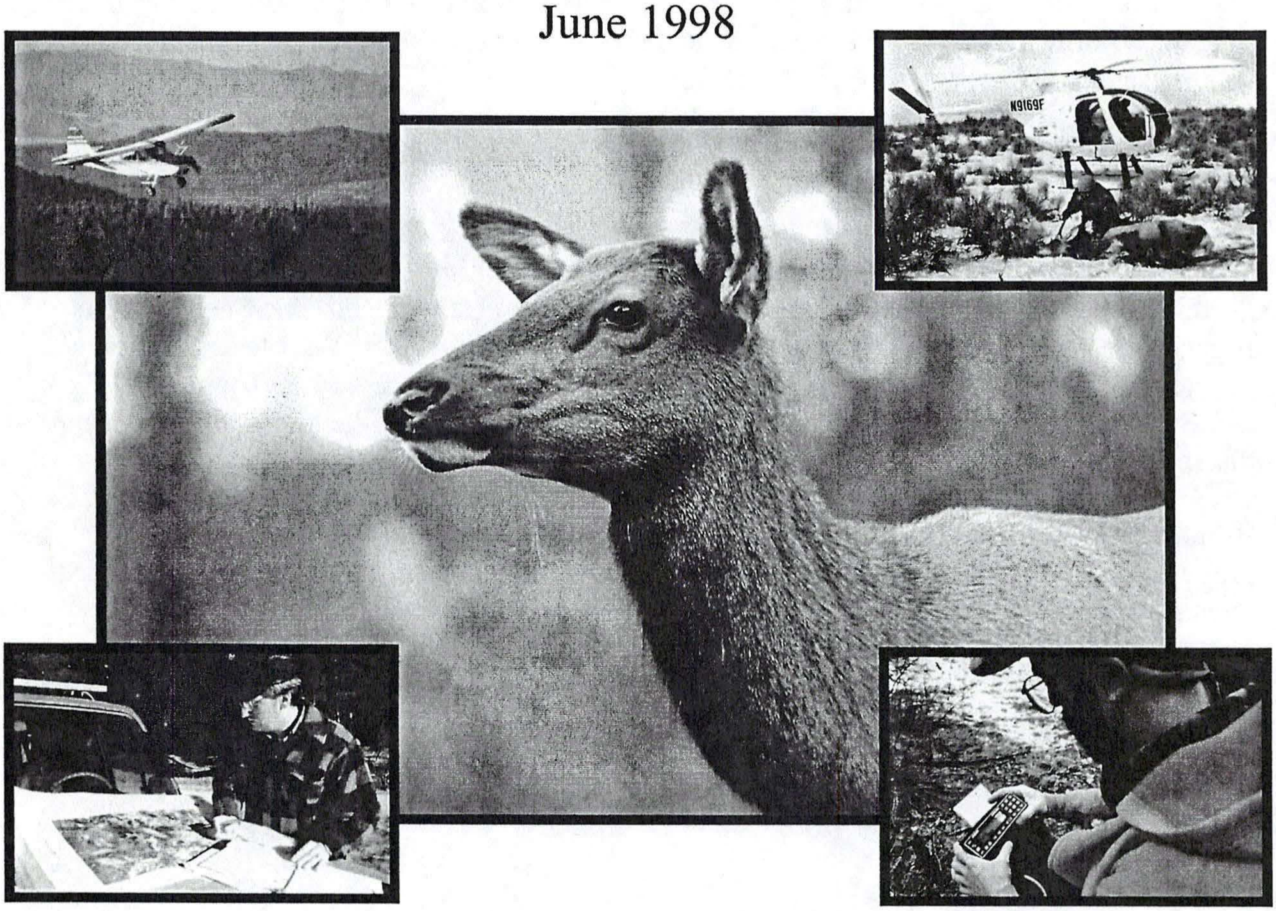

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(Numerous others were acknowledged in the final report of the 1975-1984 study, authored by: C. Les Marcum, W. Daniel Edge, Michael D. Scott, John F. Lehmkuhl and Sally L. Olson)

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This paper is dedicated to the memory of Darrell Sall, BLM Resource Area Manager during both studies.

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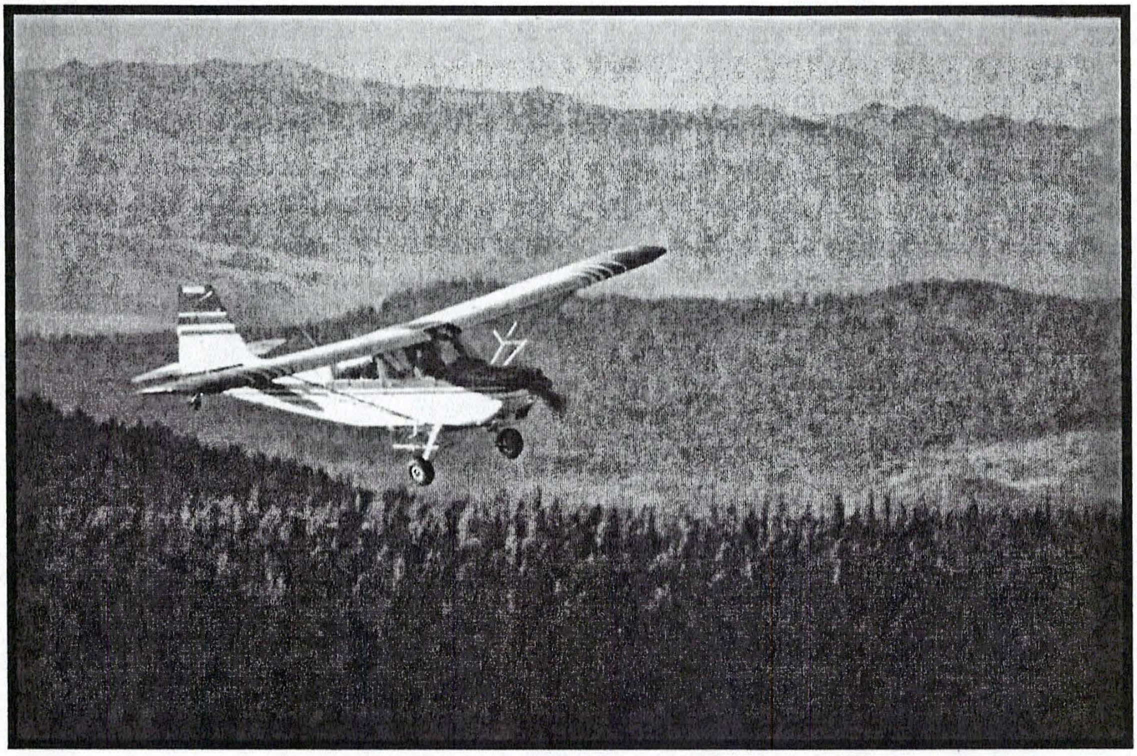
Chapter 1

INTRODUCTION



INTRODUCTION

This is a report about elk in managed forest environments. In a sense, this project began in 1971 when the Bureau of Land Management (BLM) joined the Montana Cooperative Elk-Logging Study (MCELS). The MCELS was initiated in 1970 by formal agreement between the Intermountain Forest and Range Experiment Station and Region One of the U.S. Forest Service, the Montana Department of Fish, Wildlife and Parks, and The University of Montana School of Forestry (Lyon 1971). BN Timberlands (now Plum Creek Timber Company) participated informally after 1974. The MCELS arose in response to the controversy over clear-cut logging, with an overall objective to determine "the influence of logging and road construction, together and individually, on behavior, movement, harvesting and survival of Rocky Mountain elk in Montana" (Lyon 1971:451). The BLM's Chamberlain Creek Elk-Logging Study (CCELS) was one of eight principal studies designed and initiated under the MCELS (Lyon 1980).

Richard L. Ellison of the BLM conducted the Chamberlain Creek study from 1971 through 1974. His results were described in annual reports of the MCELS, but the data he collected were not used in any subsequent analyses because of changes in data collection procedures. From 1975 to 1984 the study was conducted by personnel of The University of Montana under contract with the BLM (Marcum et al. 1984). The objectives of that study were to determine elk distribution and use of several environmental factors before, during and after logging in and near Chamberlain Creek in western Montana.

The MCELS was a highly successful cooperative effort, and much information about elk was recorded (over 70 publications, 10 from the CCELS) during the study (Lyon et al. 1985). The Montana research and similar efforts elsewhere produced a variety of approaches to improving habitat productivity by integrating elk behavior and habitat use as influenced by timber harvest, roads and disturbance (Lyon 1992). Coordinated elk/timber management guidelines were developed to reduce the impacts of logging and take advantage of its benefits (Thomas et al. 1979, Leege 1984, Lyon et al. 1985, Wisdom et al. 1986). Application of these guidelines improved elk habitat and was probably in part responsible for increased populations in most forest habitats.

Paradoxically, while Montana hunter numbers and elk harvests increased approximately 43% and 67% respectively between 1960 and 1990, unrestricted either-sex elk hunting declined from 67% to <1% of occupied elk habitat (Montana Department of Fish, Wildlife and Parks 1985, Lyon 1992). Also, the percentage of branch-antlered males in the bull harvest declined from 85% in 1963 to 42% in 1985. Bull:cow ratios of < 5:100 were observed in some Montana elk herds, while unhunted herds often have ≥ 50 branch-antlered bulls per 100 cows (McCorquodale 1991). In the 1980s and early 1990s the interest in elk increased dramatically, and hunters made it clear that simply providing numbers was an inadequate approach to elk management. Simultaneously, some biologists became concerned about the possible long-term consequences of maintaining elk herds with very low bull:cow ratios.

The strong economic stimulus to provide fiber and food from Montana's forested lands has continued. These were often the same lands where there was a high demand for

elk hunting over a continuous 5-week season, with an emphasis on mature bulls. Thus, the challenge to balance the production of forest resources with sustainable elk harvest was intense. The relationships between habitat and hunter management were not well understood. An elk vulnerability symposium (Christensen et al. 1991) was held at Montana State University, Bozeman, Montana in 1991, and a pressing need for new research was indicated. Research needs had expanded well beyond purely biological considerations. The most pressing and researchable problems involved several aspects of elk vulnerability during the hunting season, and elk response to increasing levels of habitat fragmentation.

In 1992 a cooperative comprised of the Bureau of Land Management, the USDA Forest Service Intermountain Research Station (now Rocky Mountain Research Station), The University of Montana School of Forestry, Montana Department of Fish, Wildlife and Parks, and the Plum Creek Timber Company was formed to address these questions. Later, additional funding was provided by the Rocky Mountain Elk Foundation and the Boone and Crockett Club. The Chamberlain Creek area was selected for the study because: 1) long-term data existed on the distribution, movements and habitat use by elk before, during and after logging in a previously undisturbed summer-fall range; 2) there had been continuous timber management in the area since the previous study ended in 1984; 3) it was relatively easy to document levels of human and especially hunter use of the area; and 4) some geographic information system (GIS) coverages existed for most of the study area.

Because of developments in research technology, specifically the improvements in

GIS and the availability of 30-m LANDSAT data, the analysis of data would not be confined to comparison of changes since the original study. Rather, we planned to use the original elk location data, construct both the old and new GIS habitat background coverages, and evaluate all of the data within an identical analytic frame.

The goal of the study was to determine the effects of long-term forest fragmentation on certain aspects of elk ecology and habitat use, and to determine some aspects of elk vulnerability. More specifically, the objectives were:

I. Determine pre- and postlogging movements, habitat selection and distribution of elk on both site specific and landscape scales.

II. Evaluate elk vulnerability by examining hunting season movements, habitat selections and mortality rates in Chamberlain Creek and the Blackfoot walk-in management area.

   A. Develop a hunter-density and distribution model for the walk-in area.

   B. Evaluate habitat selections and judgement errors made by elk in the Garnet Range south of the Blackfoot River.

Preliminary work on the current study was initiated during winter 1992-93, with trapping and radio-collaring of elk. In May 1993 a full-time biologist, Milo Burcham, was hired to conduct the study.

This final report is comprised of "stand alone" chapters dealing with hunter distributions, habitat selection errors made by harvested elk, elk movements and distributions, habitat selection by elk on site-specific scale, and habitat selection on a landscape scale. We have also included a chapter on our observations of the use of

private lands by elk as "refuge" areas, and a final section where we subjectively evaluate the application and results of management recommendations from both the Montana Cooperative Elk-Logging Study and the Chamberlain Creek Elk Study.

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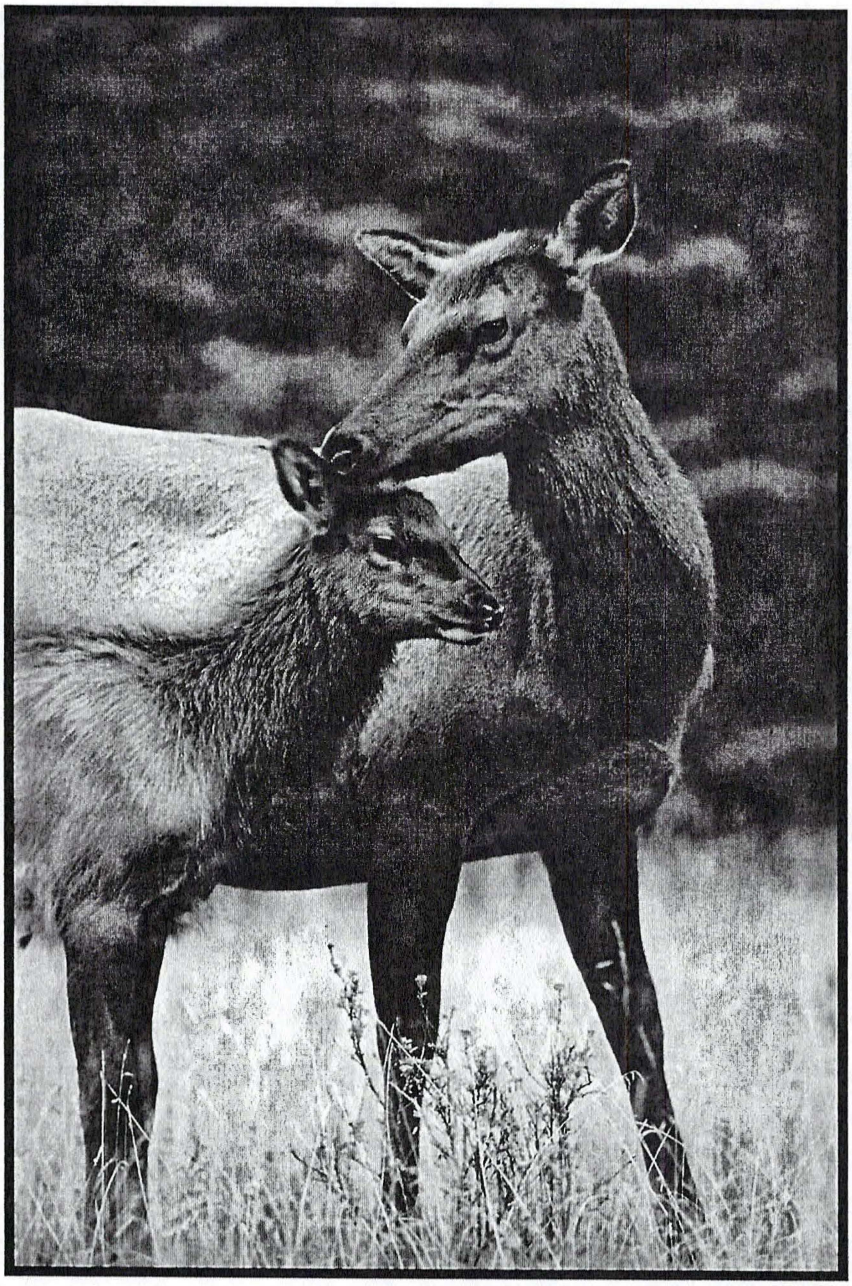
Chapter 2

LONG-TERM CHANGES IN ELK DISTRIBUTIONS IN WESTERN MONTANA



LONG-TERM CHANGES IN ELK DISTRIBUTIONS IN WESTERN MONTANA

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Abstract: It is not known if elk (*Cervus elaphus*) herds change distribution patterns over long time periods as a result of habitat modification. Our objectives were to: (1) compare elk distributions between 2 studies conducted in the same area before and after substantial habitat change, and (2) identify habitat characteristics related to elk distributions between the 2 studies. We compared distributions of radio-collared cow elk from 1977-1983 and 1993-1996 for two different elk herds. Adaptive kernal home ranges, simple and multiple linear regression, and a Poisson regression modeling approach were used to explore relationships between numbers of elk locations within grid cells, at 3 different scales, and correlate them with habitat variables. Elk distributions shifted between the 2 study periods and road variables were important in explaining these shifts. Open roads were negatively correlated with elk locations, and elk were more tolerant of roads during the second study period than during the first. Increased densities of closed roads were important in explaining decreased use of grid cells from 1 study period to the next. Elk distributions were seasonally related to forested vegetation classes. Effective management of elk herds may require regular assessment of their distribution patterns, perhaps as frequently as every 10 years.

Key Words: *Cervus elaphus*, distribution, elk, habitat change, Montana, roads.

Long-lived animals with matrilineal societies often display high degrees of home range fidelity and phylopatry (Clutton-Brock 1988). The result of this social organization is the inheritance of spatial distributions and perhaps resource selection patterns for groups of, presumably related, individuals. Over time, groups of animals that occupy better habitat would have higher fitness and a selective advantage over other groups in lower-quality habitat (Clutton-Brock et al. 1988).

Elk (*Cervus elaphus*) live in matrilineal societies, females inherent their mothers' home ranges, and some matrilineal lines consistently out perform others (Clutton-Brock et al. 1988). At the individual level, elk display a high degree of home range fidelity and do not change home range distributions when the habitat within their home ranges is modified (Hershey and Leege 1982, Edge et al. 1985*a*). Probably as a consequence of this home range fidelity and home range inheritance, elk segregate into discrete herds during the spring through fall seasons (McCullough 1969, Craighead et al. 1972, Edge et al. 1986). The spatial distribution of these herd ranges is very consistent from year to year, and constitutes a basic biological unit towards which management can be directed (Edge et al. 1986).

In forest habitats of the western United States timber management activities have the potential to modify substantial portions of elk herd ranges through timber harvest and road construction and use. The short-term response of elk to timber management activities has been a high-priority research topic for state and federal wildlife and land management agencies (Lyon et al. 1985, Johnson et al. 1991). However, most elk studies are either short-term (≤ 5 years) or

have examined responses of individual elk to timber management activities, usually using a resource selection approach to data analysis (Manly et al. 1993). No studies have examined long-term (≥ 10 years) changes in elk-herd distributions following substantial habitat modification. It is not known if elk herds change distribution patterns over long time periods as a result of habitat change or whether home range fidelity and home range inheritance might result in elk herds that consistently use the same areas regardless of habitat changes. We have conducted 2 elk studies in the same area (1977–83 and 1993–96) with an intermediate period of substantial habitat modification. The goal of this analysis was to determine if elk herds use specific areas on the landscape over long time periods, or if habitat change results in a change of elk herd distributions. Our objectives were to: (1) compare elk distributions between 2 studies conducted in the same area before and after substantial habitat change, and (2) identify habitat characteristics related to elk distributions between the 2 studies. We hypothesized that elk distributions would not differ between the 2 studies, but if they did, that changes in distribution would be associated with changes in habitat.

STUDY AREA

The Chamberlain Creek study area is located 56 km east of Missoula, Montana in the northern Garnet Mountains (Fig 1). Radio-collared elk use an area of about 210 km^2 that includes Chamberlain, Bear, Fish, Little Fish, Pearson, upper Wales, and North Fork of Elk creeks, and Cap Wallace Gulch. The Blackfoot River borders the study area to the west and north.

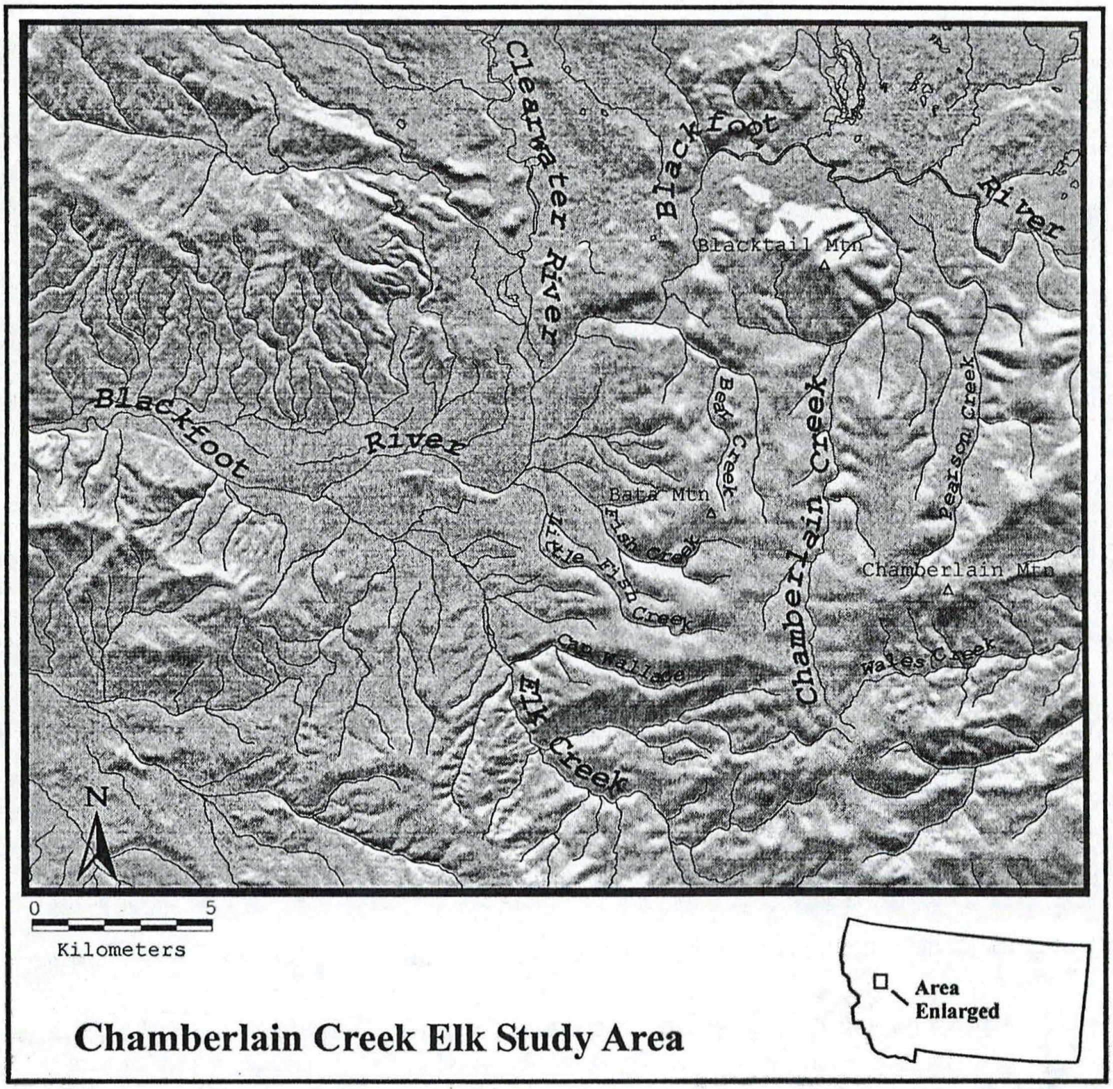


Figure 1. Chamberlain Creek Elk Study Area.

Elevations range from approximately 1,115 m along lower Elk Creek and the Blackfoot River to 2,090 m at Chamberlain Mountain on the southeast side of the study area. Topography varies from steep, high-elevation, timbered basins in the upper portions of Pearson and Wales creek drainages to open level pastures and hayfields along the southern side of the Blackfoot River north of Blacktail Mountain, and adjacent to lower Elk Creek.

Weather of the study area is typified by cool, moist winters and hot, dry summers. Weather data were collected a Lubrecht Experimental Forest (elev. 1,250 m) at the western side of the study area. The average daily minimum temperature of -13.2 C° occurs in January; the average daily maximum (28.2 C°) occurs in July. Annual precipitation varies from 30 to 74 cm, more than two-thirds of which falls in winter and spring.

Approximately 85% of the study area is forested. The forest overstory is predominately pole-size lodgepole pine (*Pinus contorta*) above 1,700 m on southerly aspects and above 1,550 m on northerly aspects. These stands resulted from extensive fires 40–90 years ago. Mature to old subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea englemannii*), western larch (*Larix occidentalis*), and Douglas-fir (*Pseudosuga menziesii*) are also found in isolated stands, predominately on north and east slopes. Subalpine fir and Englemann spruce may range down to 1,340 m in moist areas or stream bottoms. Douglas-fir dominates in nearly pure stands on dry west and south aspects below 1,700 m, while on north and east aspects, or locally moist sites, Douglas-fir occurs in mixed stands with western larch. Ponderosa pine (*Pinus ponderosa*) commonly occurs with Douglas-fir on low-elevation dry sites.

Nonforested vegetation occurs throughout the study area. Dry lower sites, such as open ridge tops and lower elevation slopes contain primarily bluebunch wheatgrass (*Agropyron*

spicatum), Idaho fescue (*Festuca idahoensis*) and arrowleaf balsam root (*Balsamorhiza sagittata*). Forbs become more abundant at higher moist sites, and arrowleaf balsamroot and giant hyssop (*Agastache urticifolia*) are common. Hay meadows and pastures are planted with Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratensis*), orchardgrass (*Dactylis glomerata*), or alfalfa (*Medicago sativa*).

Two elk herds use the Chamberlain Creek study area (Edge et al. 1986) (Fig 2). The Chamberlain Creek herd uses an area of approximately 82 km^2 in Main Chamberlain Creek, the upper portion of Pearson Creek and Blacktail Mountain. The Lindbergh herd uses a 142-km^2 area adjacent to, and south and west of the Chamberlain Creek herd, including upper Chamberlain Creek, and Bear, Fish, Little Fish, and Elk creeks. Based on annual surveys, both herds contain approximately the same number of elk. Both elk herds are more widely dispersed during years of above-normal precipitation than during years of below-normal precipitation (Marcum and Scott 1985). During the first study, the Lindbergh herd began using agricultural lands on the west side of the study area during the fall in response to the availability of high-quality forage and security during the hunting season (Edge et al. 1984). This refuge area is closed to hunting by the general public. During the second study, the Chamberlain Creek herd began using a similar refuge area, closed to hunting, north of Blacktail Mountain during the rut and hunting seasons. Short-term elk movements in response to logging disturbance (Edge and Marcum 1985), selection of feeding sites (Edge et al. 1988), habitat selection at micro and macro scales (Edge et al. 1987), and sexual segregation with respect to roads and logging disturbances (Marcum and Edge 1991) were described for the first study.

Upper elevations of the study area are managed largely by the Bureau of Land

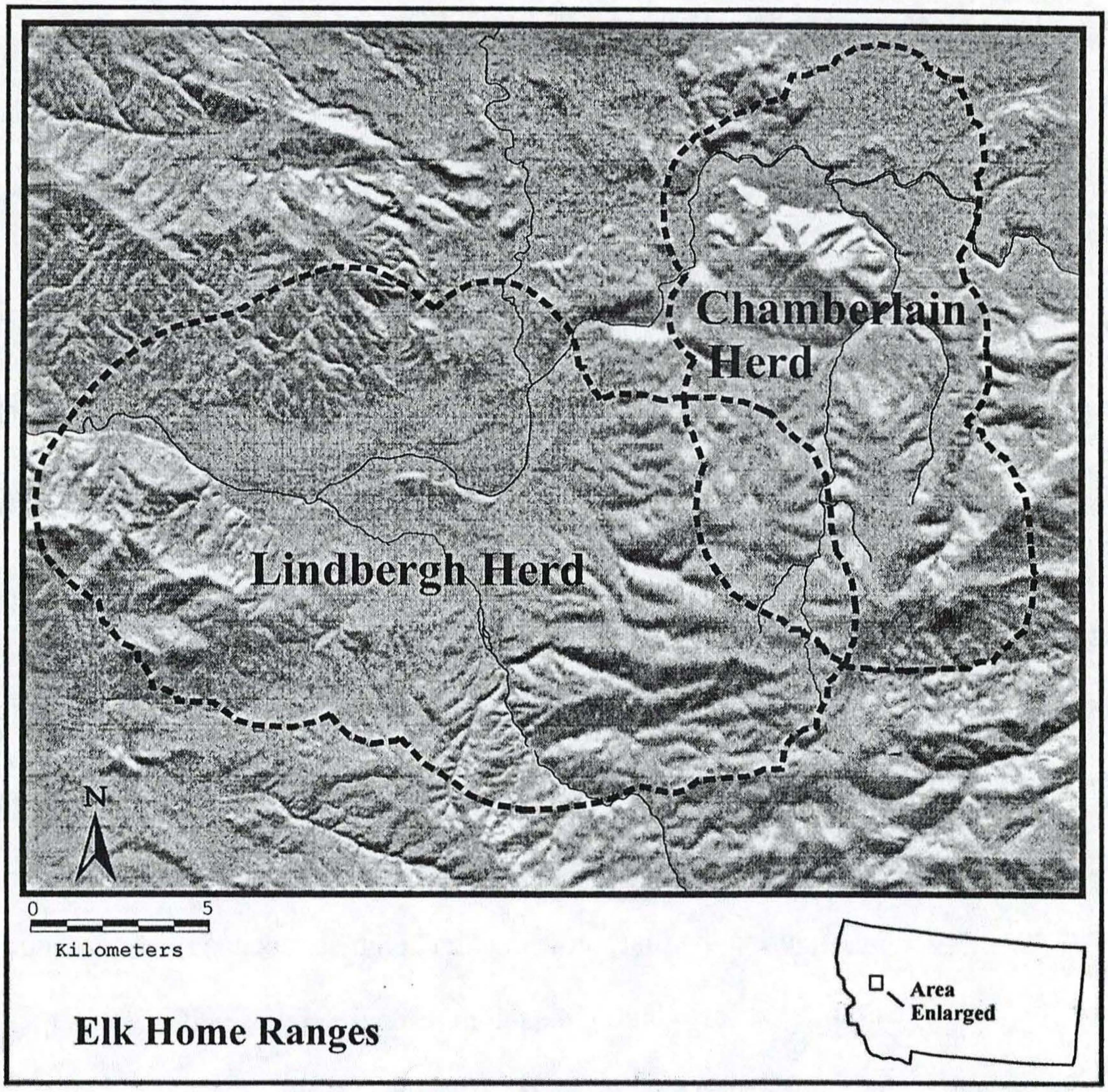


Figure 2. Cumulative 95% adaptive kernal home ranges of the two elk herds using the Chamberlain Creek Study Area.

Management (BLM) and Plum Creek Timberlands, L.P. Logging and timber production has been, and continues to be, the predominant use of the study area. Logging was extensive on the flats and rolling hills adjacent to the Blackfoot River at the turn of the century. By 1950, extensive logging and associated road construction had occurred throughout the north, northwest, and west portions of the study area. Prior to the 1980s remnant and second growth timber was heavily logged throughout Bear Creek, Little Fish Creek, and lower Chamberlain Creek. Generally, the logging has been some form of partial cutting, with some clearcuts in Little Fish, and Bear Creeks.

Prior to the start of the first Chamberlain Creek elk study, the central and upper portions of Chamberlain Creek were largely unroaded and unlogged. During the first study (1977–83), only a small proportion (≤ 5%) of the study area was logged primarily because of depressed timber prices. During the second study (1993–96), again, only minimal habitat change occurred. However, between studies extensive logging and roading occurred, especially in areas used by the Chamberlain herd, largely in the form of clearcuts and seed-tree cuts in upper Chamberlain Creek and selective logging throughout the lower Chamberlain Creek drainage. Coniferous forest cover declined from approximately 80% of the area used by the Chamberlain Creek herd to <55% of the area between the 2 studies. During that same time, coniferous cover declined by 10–15% in the areas used by the Lindbergh herd. Substantial increases in road densities occurred between the 2 studies in the Chamberlain herd areas, but no changes occurred in the Lindbergh herd areas.

Private ranches, surrounding the study area at lower elevations, are managed for hay production and cattle and horse grazing. Timber production on these private ranches takes place

on a relatively small scale in the form of selective harvests.

Hunting is the primary recreational use of these lands. Most of the study area falls within the Blackfoot Walk-In Area. This cooperative agreement between landowners and Montana Department of Fish, Wildlife, and Parks restricts vehicle access to 16,565 ha to provide security for elk and a quality experience for hunters. Elk, white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), black bears (*Ursus americanus*), moose (*Alces alces*) and mountain lion (*Felis concolor*)inhabit the area.

METHODS

Radio Telemetry

During the first study, elk were captured in corral traps baited with alfalfa during the winter and salt during the summer. During the second study, elk were capture with Clover traps (Clover 1954, Thompson et al. 1989) and by net-gunning from a helicopter. Age of captured elk were estimated by incisor replacement and wear (Quimby and Gaab 1957). Female elk were fitted with polyvinyl chloride (PVC) and acrylonitrile butadiene styrene (ABS) plastic collars containing 150–154 MHZ radio transmitters. Approximately half of the radio-collared elk were from each herd during both studies. We conducted weekly telemetry flights from mid-May through late October and twice weekly through the general hunting season (which ends in late November or early December). During the first study, airplanes were equipped with 2 strut-mounted yagi antennas; during the second study a single belly-mounted antenna was used. We recorded elk locations to ≤100 m using Universal Transverse Mercator grid coordinates. To ensure independence of observations, if ≥2 radio-collared elk were located together we only used

1 observation in our data analysis.

Geographic Information System

A geographic information system (GIS) formed the basis of our data analysis. We used PC ARC/INFO to characterize elk distributions, vegetation types and road coverages in 500, 1,000, and 2,000 m grid cells for the 2 studies. We used historical (1984) and contemporary (1992) Landsat Thematic Mapper (TM) digital coverages to classify vegetation within the study area for the 2 time periods. Vegetation polygons were first classified by unsupervised classification and 242 sites were ground-truthed during the summer of 1994. Using ground truth data, the University of Montana Wildlife Spatial Analysis Laboratory produced a supervised classification with 23 vegetation types using methods similar to those described by Hart (1994). For our analyses, we grouped these 23 vegetation types into 7 classes: agricultural and cropland (V1), sagebrush and mesic upland shrubs (V2), deciduous forest (V3), closed canopy coniferous forest (V4), open canopy coniferous forest (V5), old clearcuts with sapling regeneration (V6), and wet meadows (V7). The historical scene was created from a 1984 TM scene, intersected with a change detection layer created from differences between the 1992 and 1984 scenes. For areas that did not change, vegetation information from the 1992 map was used to provide continuity between the two time periods. For the areas that did change, vegetation polygons from the 1984 scene were inserted.

We developed a road theme using U.S. Geological Survey 7.5-min topographic maps and aerial orthophotography (1:24,000 scale). This theme was manually edited to include new roads, correct errors, and update road status information. We classified roads as open all year (R1), closed seasonally (1 Sep-30 Nov) (R2), or closed all year (R3). Year-round closed roads

received varying degrees of timber sale and administrative traffic.

Data Analysis

Initial comparisons of elk distributions between the 2 studies were made with adaptive kernal home ranges. For each herd and season, we plotted 50 and 95% isopleths to evaluate changes in home range boundaries and core areas between the 2 studies. We used the home range program CALHOME (Kie et al. 1994) to produce home range isopleths using program default values for optimum bandwidth selection and a 30 x 30 grid.

We used 2 methods for our data analysis. A series of simple and multiple linear regression analyses was used to evaluate, first, if elk distributions between the 2 time periods changed and, secondly, if these changes in elk distributions could be correlated to changes in habitat features. A modeling approach using Poisson regression was used to identify relationships between habitat features and elk distributions, and then to see if those correlations changed between herds, seasons, and most importantly, time period (Kleinbaum et al. 1988).

Because the areas used by the 2 herds are different with respect to vegetation, road densities and amount of habitat change between the 2 studies, we conducted separate analyses for each herd, or used herd as a main effect in our Poisson regression modeling. For both approaches we conducted separate analyses for 500, 1,000, and 2,000 m grid cell sizes. The number of elk locations by season and herd in each grid cell and the vegetation and road attributes of each cell formed the basis of both analyses. We combined all seasonal locations for female elk within each herd during each study and used only grid cells that contained radio-collared elk during 1 or both studies; empty cells were eliminated from our analyses. For both approaches we first eliminated 3 variables, total roads (RTOT) and old clearcuts with sapling

regeneration (V6), from our analyses because they were correlated $r^2 > 0.45$) with other variables. Also, for both approaches we eliminated grid cells that represented the private land refuge used during hunting season. These cells were eliminated because we wished to measure responses of elk to physical changes of habitat in the study area and not the behavioral response of elk to security during the hunting season.

For our linear regression analysis we asked 3 questions for each season: (1) were elk distributions during the second study correlated with elk distributions during the first study; (2) were changes in elk distributions between the 2 studies related to changes in habitat; and (3) were extreme changes in elk distributions between the 2 studies related to changes in habitat? We used proportions of elk locations within grid cells (number of elk locations within grid cell/total elk locations for that season), rather than actual counts, for each comparison to account for differences in sample size between the 2 studies. We transformed the proportion of elk locations within the grid cells with an arcsine square-root transformation to correct non-normal distributions and non-constant variances. We regressed the transformed proportion of elk locations within the grid cells during the second study against the same data for the first study. Next, we subtracted the transformed elk distributions for the second study from those of the first study to quantify changes in elk distributions between the 2 studies; we quantified changes in vegetation and road attributes for each grid cell in the same manner. We regressed changes in elk distributions between the 2 studies against changes in vegetation and road attributes between the 2 studies to determine if changes in elk distributions were related to changes in habitat. Finally, because we believed that minor changes in elk distributions between studies might occur within a natural range of variation regardless of habitat change, and because of differences in sampling

intensity, we wanted to identify grid cells with extreme changes in elk distributions. We used box plots of changes in elk distributions to identify observations that were >1.5 interquartile ranges beyond the median observation, and regressed these extreme changes against the associated changes in habitat. For both sets of multiple regression analyses we used stepwise variable selection with *P*-values to enter and remove variables set at $P \leq 0.15$.

For our second approach we used Poisson regression to model the relationship between elk distributions and habitat variables during both studies and then look for changes in the response of elk to habitat variables. We chose this approach because the count of elk locations within a grid cells could reasonably be expected to approximate the Poisson distribution. In addition, this approach allowed us to identify variables that determined elk distributions during both studies and interaction between the variables and study period. Furthermore, this data modeling approach allowed us to output predicted probabilities of elk use based on a range of explanatory variable inputs. For this analysis, we asked the following questions: (1) were elk distributions related to habitat features, and (2) did elk respond differently to habitat features over time? The number of independent elk locations within a grid cell were regressed against variables representing 3 road classes and 7 vegetation classes, as well as herd, season, and time period as main effects. Differences in the sample sizes for herds and seasons were accounted for by using an offset variable (ln(N)). We used backwards elimination of variables, repeatedly removing the least significant variable from the model, one at a time, until only significant ($P \leq 0.05$) variables remained. Once the important variables were identified, we then constructed a model that included interactions of significant habitat variables and main effect variables (study period (T), herd (H), and season(S)). This model was created using backwards elimination as

described above.

We performed a sensitivity analysis of each variable in the best models for each scale. We entered a range of values for the variable (quartiles ranging from 0 to the maximum value for that variable at a given season and herd), while the other variables were held constant at their means for each herd. This allowed the influence of each variable on the models to be explored, within ranges representative of the study area.

RESULTS

During the first study we obtained 2,837 radio location from 66 female elk between mid-May and early December, 1977 through 1983. We obtained 2,021 locations from 39 female elk from mid-May and early December, 1993 through 1996 during the second study (Appendix A). We observed elk at telemetry locations 51% of the time for the first study and 62% of the time for the second study.

Herd ranges and core areas had similar external configurations, especially for the Chamberlain herd. Chamberlain old and new seasonal herd ranges averaged 64% overlap while those for the Lindbergh herd averaged 40% (Table 1). Seasonal herd range overlap increased from parturition through the rut for both herds. The change in distribution of the Lindbergh herd occurred as a shift towards private lands at lower elevations during all seasons.

Simple and Multiple Linear Regression

Seasonal elk distributions during the second study were generally correlated with elk distributions during the first study, but the relationships were weak (17 of 24 significant [$P \leq 0.1$] r^2-values ≤ 0.2; Table 2). In general, r^2-values increased with scale, were higher for the

Table 1. Percent overlap between first (1977–83) and second (1993–96) seasonal herd ranges (95% isopleth) for the Chamberlain and Lindbergh elk herds.

		Season				
Herd	Isopleth (%)	Parturition	Summer	Rut	Hunting	Mean
Chamberlain	95	59	68	71	58	
Lindbergh	95	29	39	42	49	40

Chamberlain Creek herd than the Lindbergh herd, and increased from parturition through the hunting seasons for both herds.

Changes in elk distributions between the 2 studies were generally related to changes in habitat for all seasons for both herds except for the Chamberlain herd during parturition and the Lindbergh herd during the hunting season (Table 3). Again, strength of the relationships increased with scale and models for the Chamberlain Creek herd tended to have higher r^2-values than the Lindbergh herd models. Density of year-round closed roads was the most prevalent independent variable for the Chamberlain models, especially during the summer and rutting seasons. Density of year-round closed roads was an important variable during the rut for the Lindbergh herd. In all models in which density of year-round closed roads was a significant variable, road densities were negatively correlated with changes in elk distributions except during parturition for the Chamberlain herd. Changes in elk distributions were positively correlated to the amount of closed canopy coniferous forest (V4) and open canopy coniferous forest (V5) during the rutting and hunting seasons for the Chamberlain herd. Negative correlations between the amount of sagebrush and mesic upland shrubs and changes in elk distributions were common in Lindbergh herd models.

When only extreme changes in elk observation are used the relationships between changes in elk distributions and habitat-change variables were stronger (Table 4). Changes in elk distributions were negatively correlated to the density of year-round closed roads during the summer and rutting seasons for the Chamberlain herd and during parturition, summer, and rut for the Lindbergh herd. Changes in elk distributions were positively correlated to the amount of closed canopy coniferous forest (V4) or open canopy coniferous forest (V5) during the rutting

Table 2. Correlation of elk distributions in 500-, 1,000-, and 2,000-m grid cells during first and second studies in Chamberlain Creek by season and herd, using all observations.

		Herd							
	Grid cell size (m)	Chamberlain				Lindbergh			
Season		n[b]	r^2	F	P	n	r^2	F	P
Parturition	500	105	0.039	4.26	0.042	147	0.037	5.58	0.019
	1,000	52	0.028	2.51	0.119	84	-0.012	0.000	0.991
	2,000	18	0.199	3.98	0.063	36	0.049	2.82	0.102
Summer	500	200	0.005	0.09	0.777	247	0.014	4.40	0.037
	1,000	77	0.032	3.59	0.062	119	-0.002	0.81	0.371
	2,000	27	0.261	10.19	0.004	50	0.086	4.51	0.039
Rut	500	182	0.013	2.43	0.121	220	0.006	1.27	0.262
	1,000	94	0.021	3.01	0.086	107	0.063	8.15	0.005
	2,000	36	0.271	12.64	0.001	48	0.119	6.23	0.016
Hunting	500	124	0.010	1.28	0.260	164	0.034	6.37	0.012
	1,000	62	0.086	6.97	0.011	97	0.065	7.77	0.006
	2,000	27	0.435	19.28	0.000	40	0.137	6.01	0.019

[a] Transformed proportions of elk observations within a grid cell.

[b]Number of grid cells.

Table 3. Multiple regression of changes in elk distributions[a] in 500-, 1,000-, and 2,000-m grid cells against changes in road and habitat variables between first and second studies in Chamberlain Creek by season and herd.

	Grid size (m)	Herd									
		Chamberlain					Lindbergh				
Season		n[b]	Variable in model[c]	R^2	F	P	n	Variable in model	R^2	F	P
Parturition	500		No variables			>0.15	147	-V2	0.086	13.72	0.001
	1,000	53	R3	0.071	3.88	0.054	84	-V2	0.231	24.58	0.001
	2,000		No variables			>0.15	36	-V2	0.327	16.54	0.001
Summer	500	200	-R3 V1	0.068	7.19	0.001	247	-V2 V7 V1	0.033	2.72	0.045
	1,000	78	-R3	0.117	10.04	0.002	120	-V5 -V2	0.084	5.37	0.006
	2,000		-R3 V1	0.481	11.12	0.001	50	-V3	0.118	6.41	0.015
Rut	500	182	V5 -R3	0.048	4.54	0.012	220	-V2	0.044	10.12	0.002
	1,000	95	V4 -R3 V5	0.159	5.73	0.001	108	-R3 -V5 -V2	0.112	4.36	0.006
	2,000	36	-R3 V5	0.209	4.36	0.021	48	-V2 -R3	0.214	6.13	0.004
Hunting	500	124	V5	0.091	12.31	0.001		No variables			>0.15
	1,000	63	V4 -V1	0.255	10.42	0.001	98	No variables			>0.15
	2,000	27	V4	0.416	17.79	0.001	40	-V4 V2	0.187	4.26	0.022

[a] Transformed proportions of elk observations within a grid cell.

[b]Number of grid cells.

[c]Variables are listed in order that they entered the model. Minus sign in front of variable indicates a negative relationship between change in elk distribution and independent variable. Variable names: V1 = agricultural and cropland (%); V2 = sagebrush and mesic upland shrubs (%); V3 = deciduous forest (%); V4 = closed canopy coniferous forest (%); V5 = open canopy coniferous forest (%); V7 = wet meadows (%); R1 = year-round open roads (m); R2 = seasonally closed roads (m); R3 = roads closed year-round (m).

and hunting seasons for the Chamberlain herd. However, changes in elk distributions for the Lindbergh herd were negatively correlated to the amount of open canopy coniferous forest (V5) and sagebrush and mesic upland shrubs (V2) during the summer and rutting seasons.

Poisson Regression

Poisson models predicting the proportion of seasonal elk locations within grid cells were weak, with R^2-values $\leq$ 0.23 (Table 5). As in the linear models, R^2-values increased with scale. Year-round open roads (R1) appeared in the models at all scales and were always negatively correlated with the proportion of elk locations within grid cells. Seasonally closed roads (R2) were negatively correlated with proportions of elk locations in the 1,000-m model, sagebrush and mesic upland shrubs (V2) were negatively correlated with elk locations in 2 models, and closed canopy coniferous forest (V4) was positively correlated with elk locations in 2 models.

Forest vegetation types, both closed canopy coniferous forest (V4) and open coniferous forests (V5), appeared in all of the Poisson models, indicating the importance of forest cover to elk distributions (Table 6). These variables were positively correlated to elk locations at the 1,000 and 2,000 m scales, however, open canopy coniferous forest (V5) was negatively correlated within 500 m grid cells. These variable each interacted with themain effect variable SEASON in separate Poisson models, indicating that this relationship changed seasonally. Generally, closed canopy coniferous forest (V4) was positively correlated with elk locations during the rut and hunting seasons, and negatively correlated during calving season (Figs. 3-4). Open canopy coniferous forest (V5) showed opposite seasonal correlations: a negative correlation with the rut, hunting season, and summer distributions, and a positive correlation during calving season (Figs.5-6). No HERD interaction with closed (V4) or open (V5)

Table 4. Multiple regression of extreme changes in elk distributions[a] in 500- 1,000- and 2,000-m grid cells against changes in road and habitat variables between first and second studies in Chamberlain Creek by season and herd.

Season	Grid size (m)	Chamberlain n[b]	Chamberlain Variable in model[c]	Chamberlain R^2	Chamberlain F	Chamberlain P	Lindbergh n	Lindbergh Variable in model	Lindbergh R^2	Lindbergh F	Lindbergh P
Parturition	500		No variables			> 0.15	8	-R3	0.527	6.69	0.041
	1,000	8	R3	0.556	7.53	0.034	6	-R3	0.833	19.90	0.011
	2,000		No variables			> 0.15	6	-R3	0.866	25.85	0.007
Summer	500	52	-R3 V1	0.129	3.65	0.033		No variables			> 0.15
	1,000	8	No variables			> 0.15	24	-V5 -V2	0.317	4.87	0.018
	2,000	5	-R3 V1	0.968	30.21	0.032	11	-V3 -R3	0.545	4.80	0.043
Rut	500	19	-R3	0.176	3.63	0.074	63	-V2	0.056	3.60	0.062
	1,000	14	V4 -R3 V1	0.699	7.75	0.006	20	-R3 -V5	0.384	5.31	0.016
	2,000	9	-V1 -R3	0.749	8.98	0.016		No variables			> 0.15
Hunting	500	20	V4	0.118	2.41	0.138		No variables			> 0.15
	1,000	9	V4	0.691	15.64	0.006	3	V1	0.965	27.56	0.119
	2,000	7	V5 R2	0.857	12.03	0.020		No variables			> 0.15

[a]Transformed proportions of elk observations within a grid cell.

[b]Number of grid cells.

[c]Variables are listed in order that they entered the model. Minus sign in front of variable indicates a negative relationship between change in elk distribution and independent variable. See Table 3 or text for variable names.

Table 5. Poisson regression models of elk distributions and habitat characteristics for first and second studies in Chamberlain Creek by grid cell size.

Grid size (m)	*n*[a]	Variables in model[b]	R^2	R^2_{adj}[c]	*F*	*P*
500	2,777	-R1, -V5, -V2, R1 * T, V5 * S, V2 * T	0.09	0.14	306.06	0.000
1,000	1,399	-R1, -R2, V4, -V2, R1 * T, V2 * T, V2 * S, V2 * H, V4 * S	0.14	0.79	530.46	0.000
2,000	563	-R1, V5, V4, R1 * T	0.23	0.97	1243.86	0.000

[a]Number of grid cells.

[b] Minus sign in front of variable indicates a negative relationship between proportions of elk locations in a grid cell and independent variable. Interactions between variables and time (T), season (S), and herd (H) are denoted by *. See Table 3 for variable names.

[c] Adjusted R^2 as described by SAS Institute Inc. (1995).

coniferous forests appeared in the models, so predicted trends were similar for the Chamberlain and Lindbergh herds (Figs. 3-6).

The interaction of year-round open roads (R1) and time (T) was significant ($P \leq 0.05$) in models at each scale. Our sensitivity analyses suggest that elk were more responsive to year-round open roads during the first study than during the second (Figs.7-8). Although the proportions of elk locations within grid cells declines with increasing amount of roads within each grid cell for both study periods, this decline was less pronounced during the second study. At open road densities <1 km/km^2, proportions of elk locations within grid cells were indistinguishable for the 2 study periods. The amount of shrubland (V2) within a grid cell interacted with herd at the 1,000-m scale because this vegetation type was more common in the Lindbergh herd than in the Chamberlain herd. Shrubland also interacted with study period (T) at both 500 and 1,000 m scales because of the shift to lower elevations by the Lindbergh herd during the second study. Interactions of season with closed canopy coniferous forest (V4), and open canopy coniferous forest (V5) reflect the changing importance of these vegetation types throughout the year.

DISCUSSION

Our analyses indicate that the 2 elk herds using the study area shifted distributions substantially during the 10 years between studies. However, examination of the original point location data suggests that real changes in elk distribution were far less dramatic than implied by overlap of 95% kernal home range isopleths. The general shapes of herd ranges changed little between the 2 studies, but the proportion of cow elk locations within a grid cell in the first study

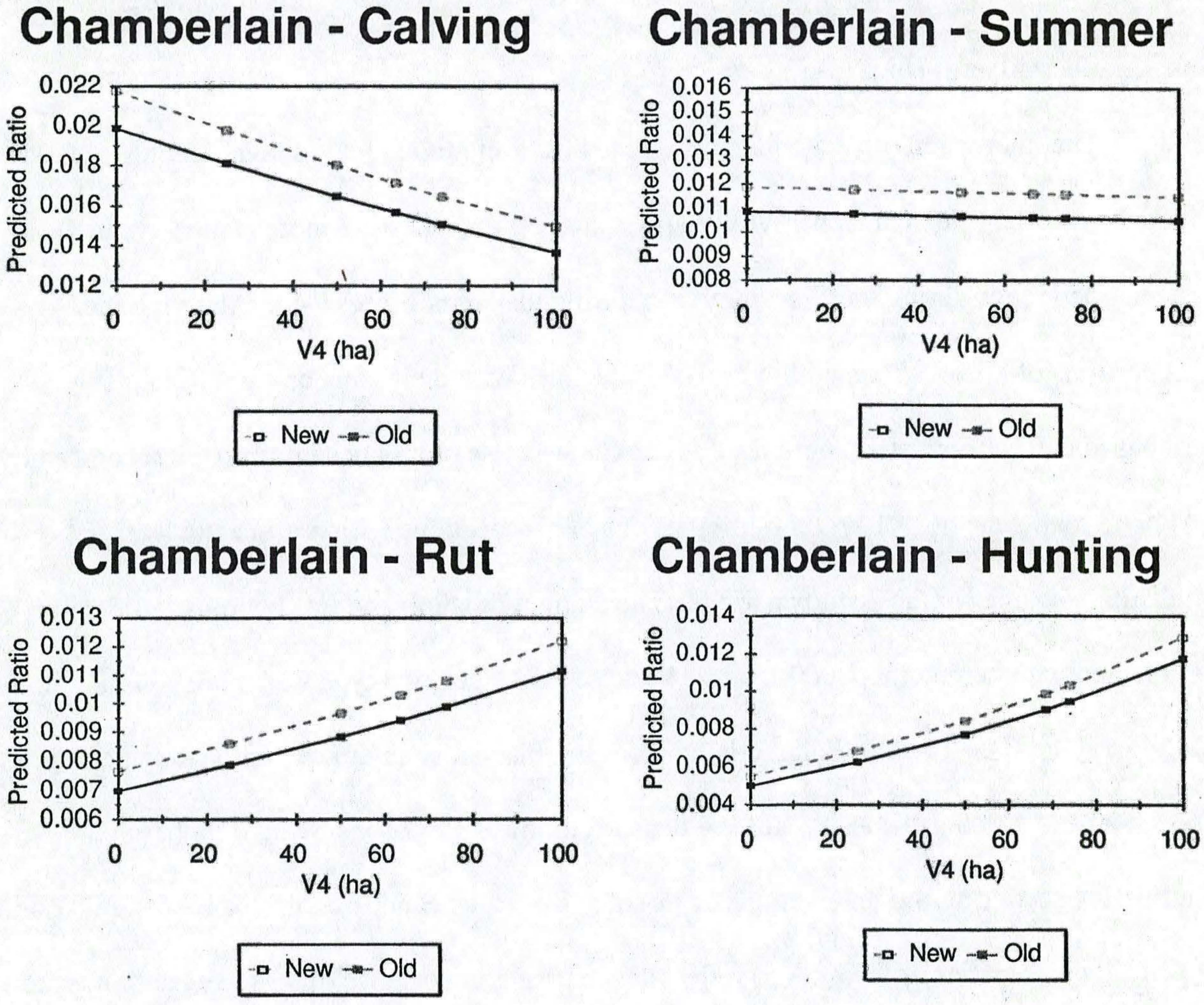


Figure 3. Sensitivity analysis of Poisson Regression model of correlation between closed canopy coniferous forest (V4) and the proportion of Chamberlain elk locations within 1,000 m grid cells. Difference between lines for old and new study periods are not significant ($P \leq 0.05$).

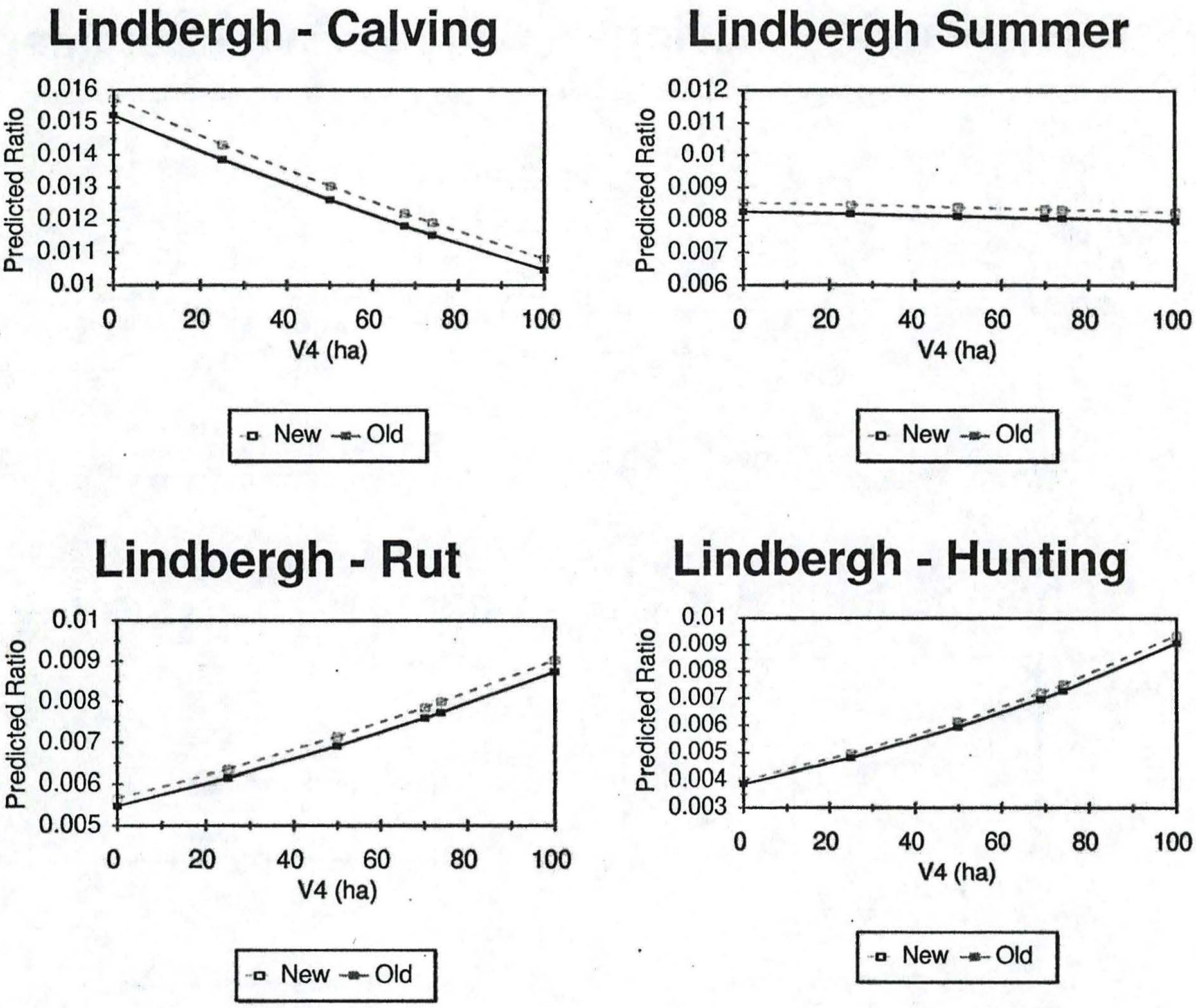


Figure 4. Sensitivity analysis of Poisson Regression model of correlation between closed canopy coniferous forest (V4) and the proportion of Lindbergh elk locations within 1,000 m grid cells. Difference between lines for old and new study periods are not significant ($P \leq 0.05$).

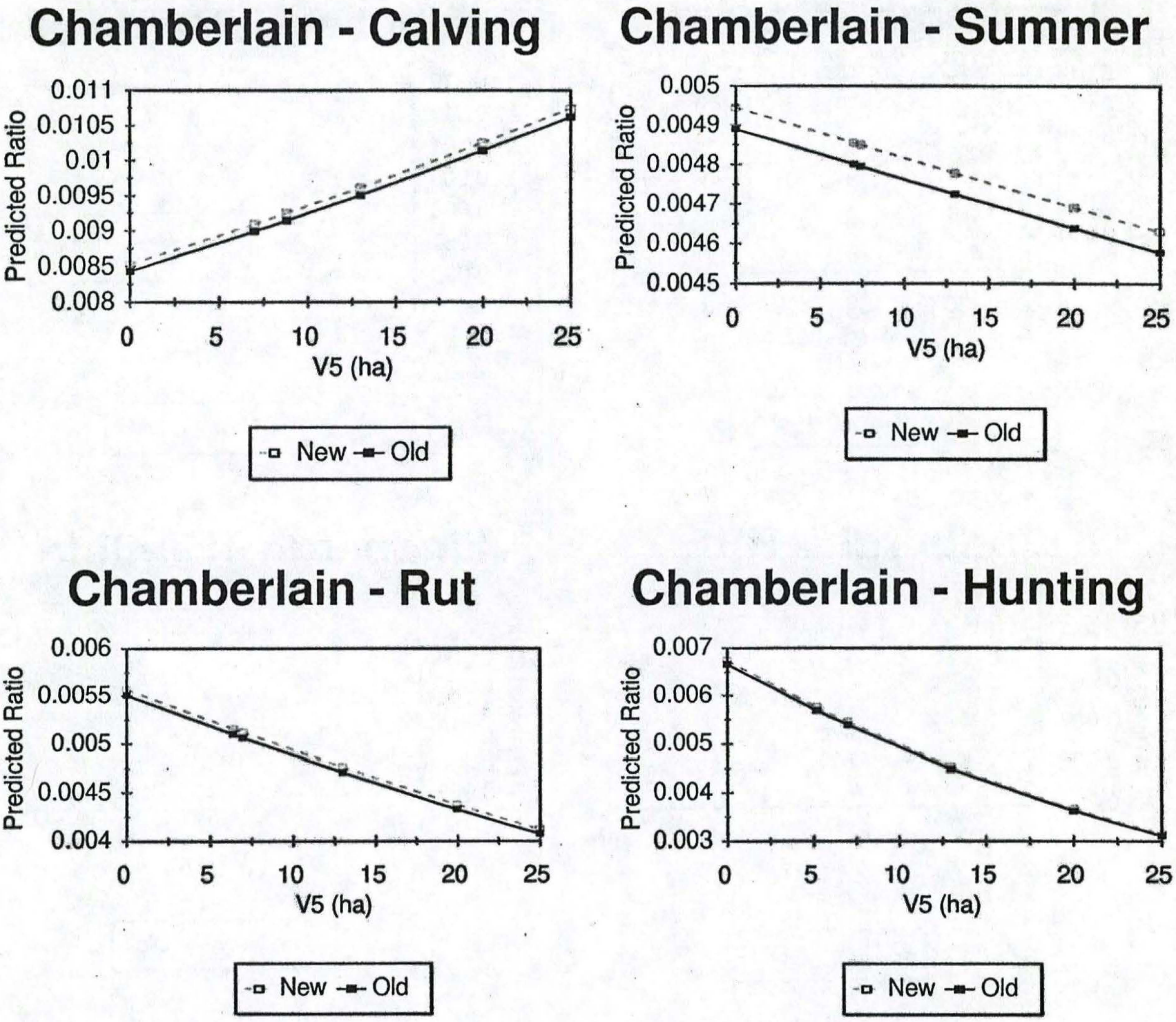
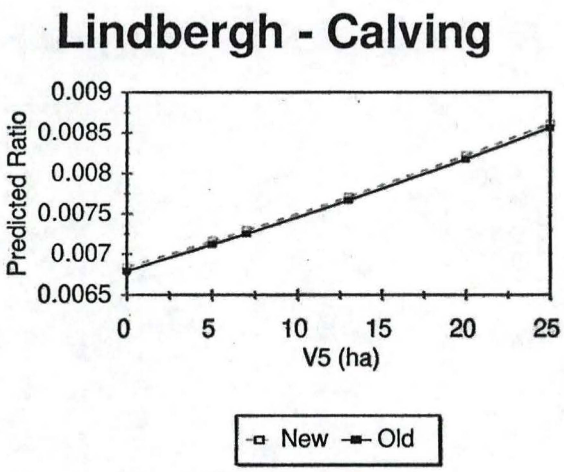
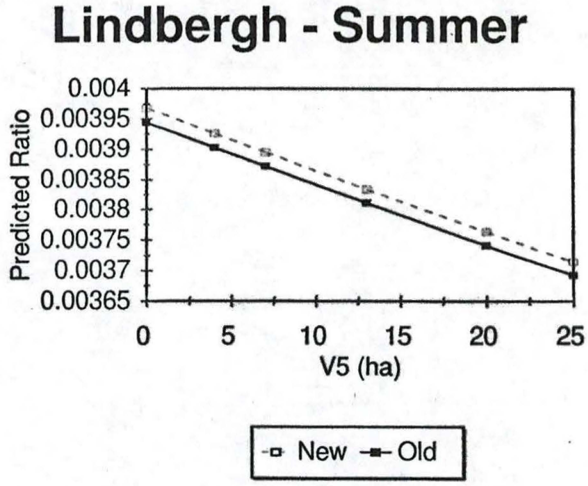
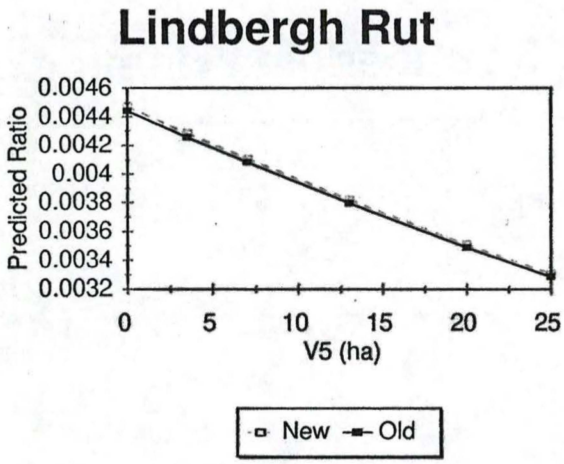


Figure 5. Sensitivity analysis of Poisson Regression model of correlation between open canopy coniferous forest (V5) and the proportion of Chamberlain elk locations within 500 m grid cells. Difference between lines for old and new study periods are not significant ($P \leq 0.05$).







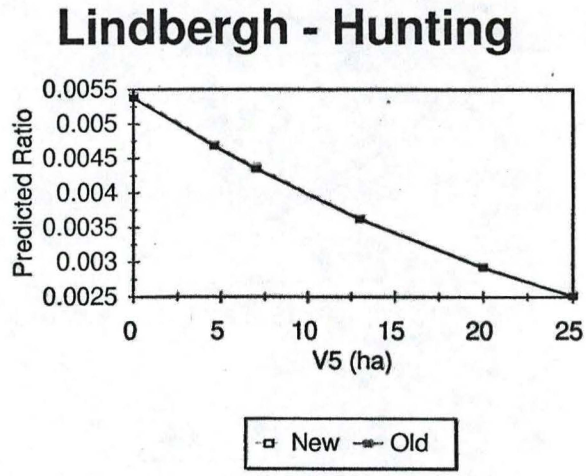


Figure 6. Sensitivity analysis of Poisson Regression model of correlation between open canopy coniferous forest (V5) and the proportion of Lindbergh elk locations within 500 m grid cells. Difference between lines for old and new study periods are not significant ($P \leq 0.05$).

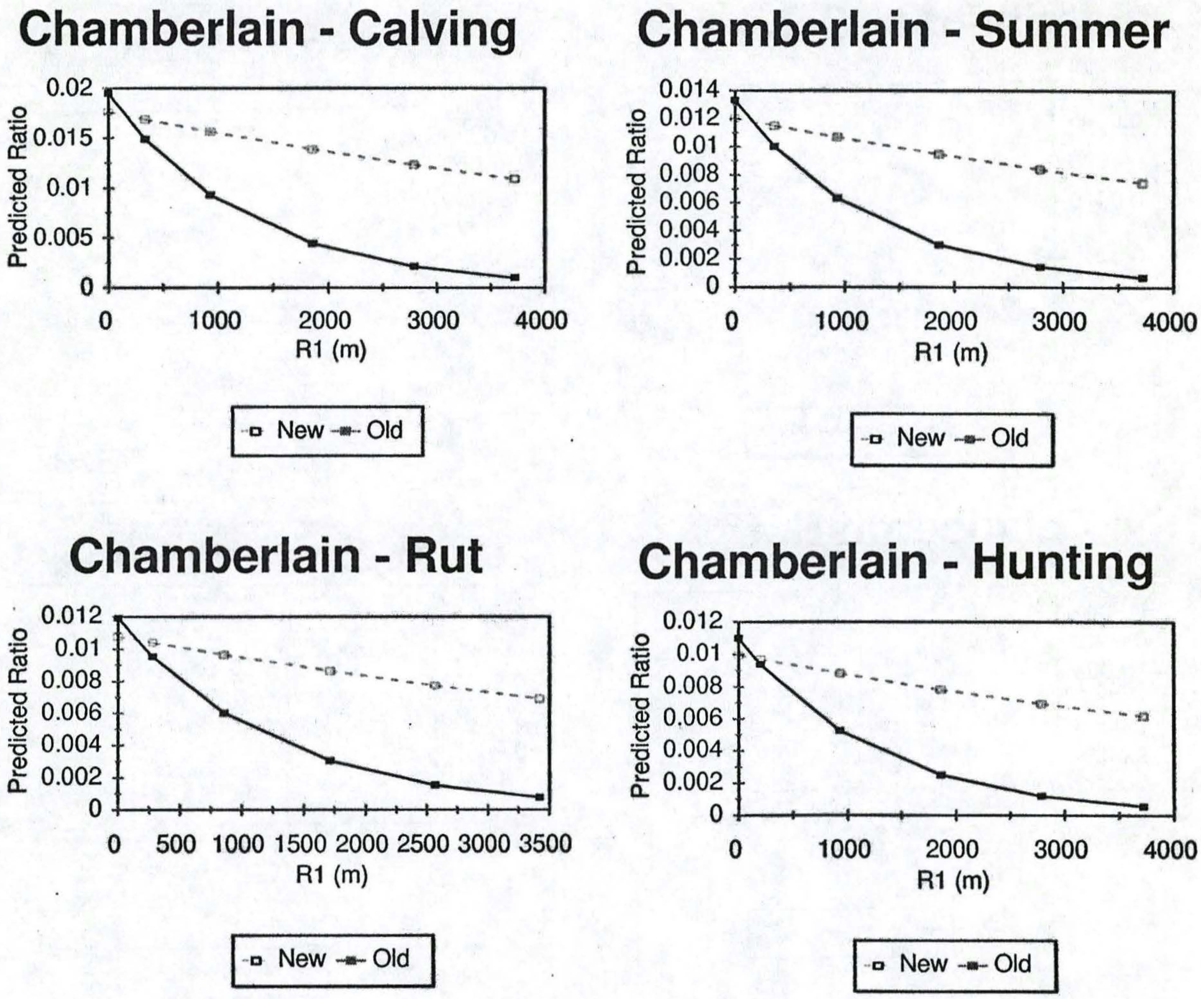


Figure 7. Sensitivity analysis of Poisson Regression model of correlation between year-round open roads (R1) and the proportion of Chamberlain elk locations within 1,000 m grid cells. Lines for old and new studies become significantly different ($P \leq 0.05$) above approximately 1,000 m of open road.

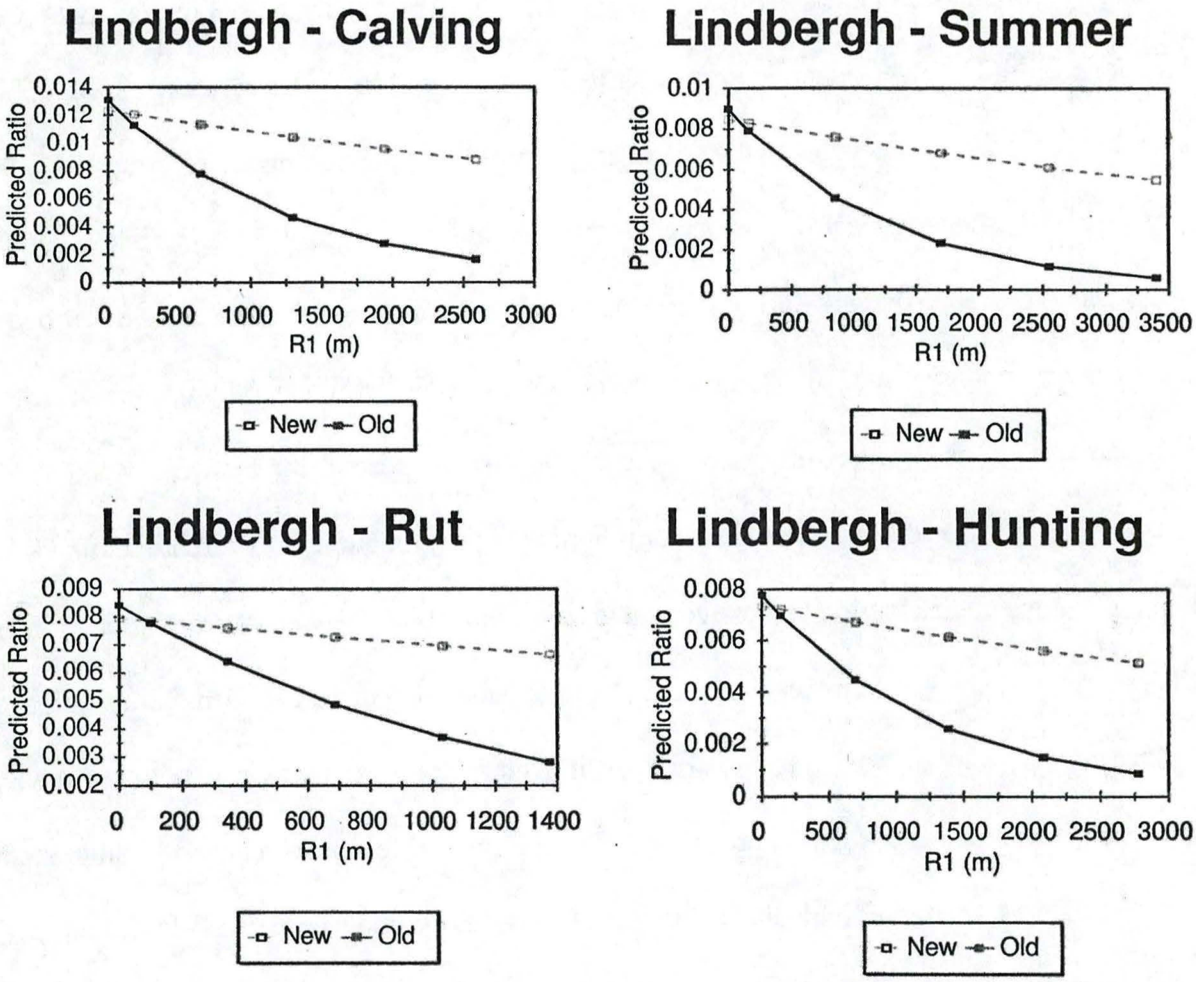


Figure 8. Sensitivity analysis of Poisson Regression model of correlation between year-round open roads (R1) and the proportion of Lindbergh elk locations within 1,000 m grid cells. Lines for old and new studies become significantly different ($P \leq 0.05$) above approximately 1,000 m of open road.

was a poor predictor of elk locations in the second study. The appearance of the raw data point locations for the Lindbergh herd confirms shifts in elk use within a relatively large geographic area, but there was little evidence that elk abandoned old areas or colonized new ones (Fig. 9). In a much smaller geographic area, the distribution of point locations for the Chamberlain herd provides no evidence that elk during the second study are not using the same areas described during the first study (Fig. 10). Again, however, both elk herds still generally use the same ranges, correlations between the grid cell use for the first and second studies were weak.

The shift in distribution of the 2 herds appear to be a function of different factors for each herd. Changes in distribution associated with changes in habitat were most pronounced for the Chamberlain herd where the greatest modification of habitat occurred between the 2 studies. Elk in Chamberlain herd decreased use of grid cells in which densities of year-round closed road increased. Avoidance of roads is probably the most universal response detected in other studies based on radio-tracking individual elk (Lyon et al. 1985, Edge and Marcum 1991, Cole et al. 1997). Furthermore, several seasonal models for the Chamberlain herd identified a positive relationship between changes in elk distributions and coniferous forest and cover types. Closed canopy forest were important seasonal habitat during our first study (Edge et al. 1987) and have been identified as important components of elk habitat elsewhere (Wisdom et al. 1997).

The change in distribution was most pronounced for the Lindbergh herd, where the least amount of habitat change occurred. The shift in the Lindbergh herd appear to be associated with year-round use of private lands closed to public access, and less related to changes in habitat conditions per se. A few elk in the Lindbergh herd began using hay meadows and irrigated alfalfa fields on the west side of the study area during the 1980 hunting season in response to the

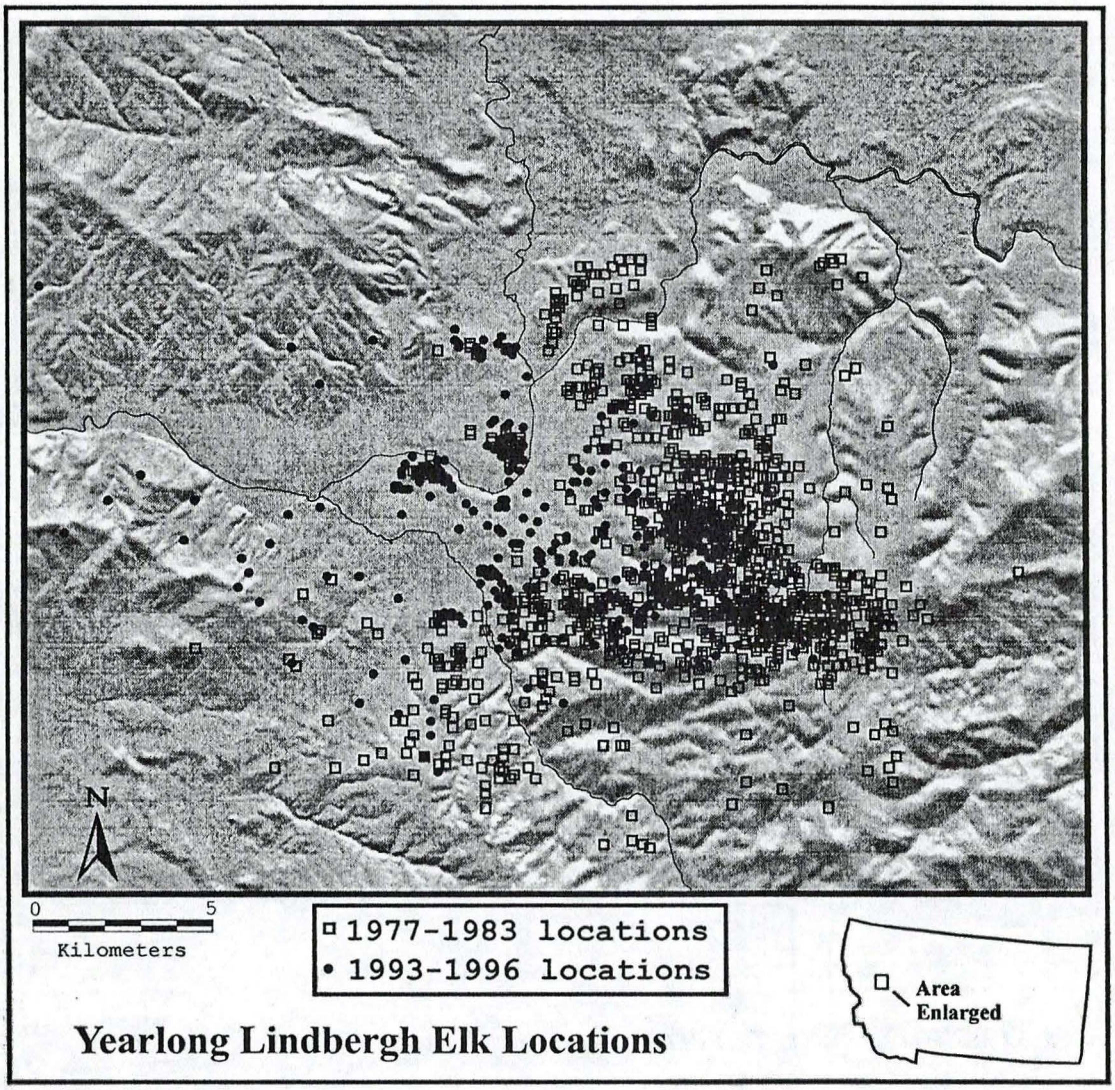


Figure 9. Distribution of yearlong Lindbergh elk locations for the old and new study periods.

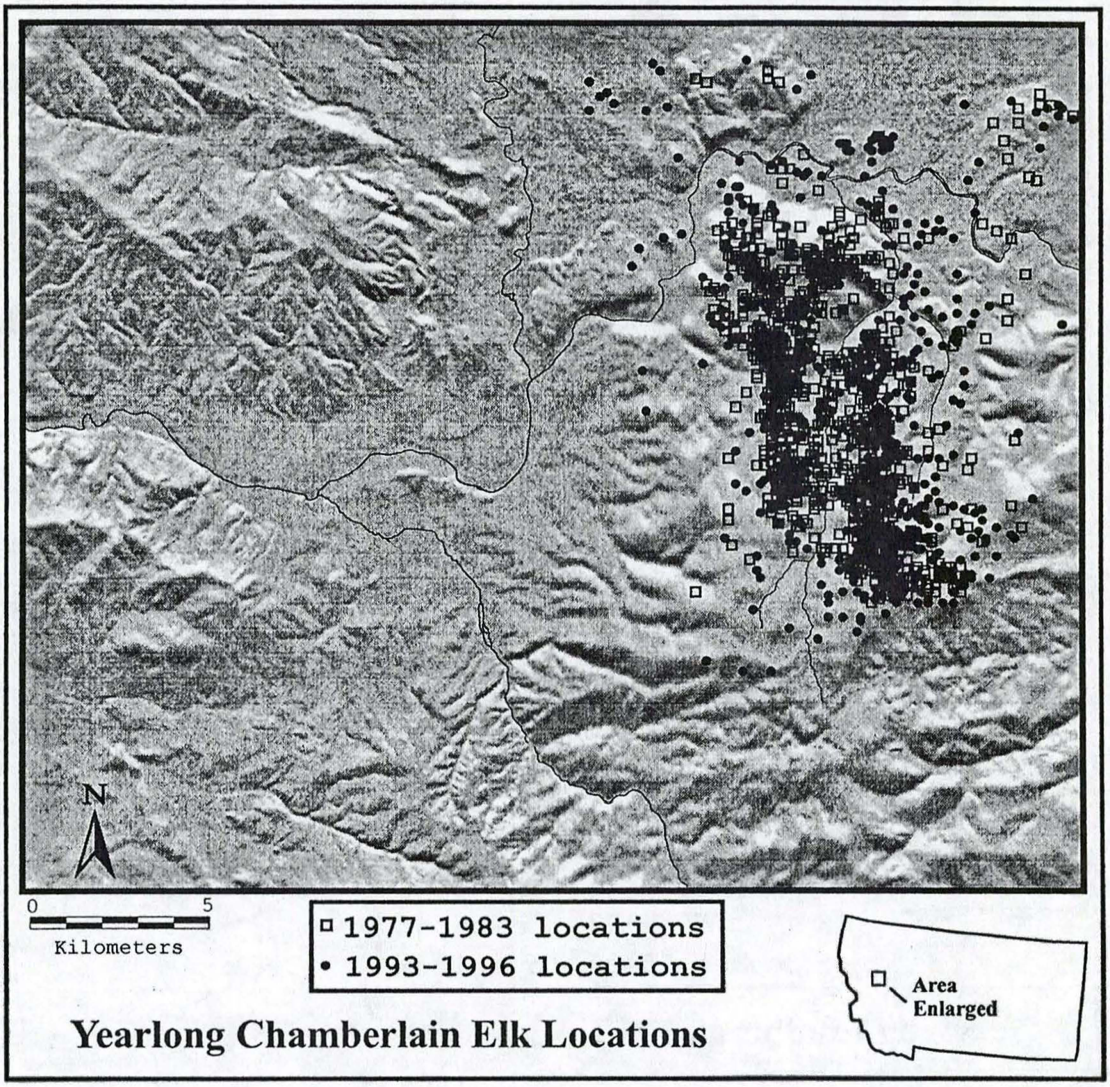


Figure 10. Distribution of yearlong Chamberlain elk locations for the old and new study periods.

availability of the high-quality forage and security during the hunting season (Edge et al. 1984). By the end of the first study (1983) >75% of the Lindbergh herd used this area; however, use was limited to the late rut and hunting seasons. During the period between studies, the Lindbergh herd began using this refuge area on a year-round basis resulting in seasonal herd ranges and core areas which are centered on low elevation private lands with less cover and a concurrent decreased in use of the upper Chamberlain Creek drainage, which is almost continuous cover.

Forest vegetation types appeared in each of the Poisson models, revealing mostly positive correlations with forested cover. A closer inspection of this relationship, however, indicated that elk use of coniferous forest types differed seasonally (Figs.3-6) Closed canopy forests were positively correlated with elk distributions during the rut and hunting season, while open canopy forests showed negative correlations for those seasons. Elk appeared to differentiate closed canopy forests from open canopy forests, namely during the rut and hunting season when elk require security cover. Open canopy coniferous forests were positively correlated with elk locations during calving season, possibly for the greater forage values and predator avoidance, while closed canopy forest showed negative correlations during this season.

Our Poisson regression modeling suggests that elk may display long-term changes in behavioral responses to habitat attributes, especially roads. Year-round open roads was the most important variable, appearing in models at each scale. Elk distributions were always negatively correlated with the amount of year-round open roads within grid cells, but this response was more pronounced during the first study than during the second study (Fig. 3)., This apparent change in response over time may be a function of elk habituating to the regular disturbance of year-round open roads and the association of these roads in our study area with the refuge on

private lands, especially for the Lindbergh herd. Other studies have reported that elk habituate to regularly traveled roads. Ward et al. (1980) reported that elk avoided infrequently traveled roads to a greater extent than an interstate highway system. Elk in Yellowstone National Park habituate to roads and human activities associated with these activities (Schultz and Bailey 1978). Year-round open roads within the Lindbergh herd range consisted of State Highway 200, and unpaved county roads crossing private ranch lands at lower elevations, and approaching access points to the road closure areas. The shift in distributions for the Lindbergh herd brought elk in closer proximity to these roads on a year-round basis. However, the lack of an interaction of year-round open roads and herd suggests that the changing response to year-round open roads occurred for both herds. Thus, this changing response to open roads cannot be explained entirely by the Lindbergh herd using the lower elevation private lands in close proximity to roads.

Our study of changes in distribution of 2 elk herds generally reaffirm inferences regarding habitat selection based on radio-tracking of individual animals. In particular, roads continued to be the most important factor in determining elk use of habitat at both the individual and herd scale (Lyon et al. 1985, Edge and Marcum 1991, Cole et al. 1997). Year-round open roads was the most important variable explaining elk distributions in our Poisson regression analyses, and, although elk response to these roads was less pronounced during the second study, the relationship between elk distributions and open road densities was always negative. Increased density of year-round closed roads was commonly associated with a decrease in the proportion of elk locations within a grid cell between the 2 studies. The fact that closed roads were an important variable suggests that even sporadic traffic may cause avoidance of an area by elk. Year-round closed roads within the study area were used for timber sale traffic and

administrative use. Recently constructed closed roads, those associated with declines in elk use within grid cells, would have received the largest volume of vehicular traffic associated with harvest activity and associated administrative use. Even this level of vehicle activity may have reinforced and maintained avoidance behavior by elk.

The contrast in variables selected in our linear and Poisson regression analyses can be explained by the questions each approach addressed. Year-round closed roads did not appear in any Poisson model, even though they were important in the linear regression models. The linear regression models used changes in habitat variables and elk distributions, while the Poisson analysis modeled elk use and road attributes of grid cells over both study periods. Year-round closed roads were the road class that changed the most between the studies and these changes helped explain changes in elk use. Year-round open roads and seasonally closed roads changed very little between the 2 studies, and therefore, offered little discriminating power for the linear regression analysis.

MANAGEMENT RECOMMENDATIONS

Edge et al. (1986) proposed an approach for determining the spatial distribution of female elk herds, and suggested that these distributions and herds form the basic biological unit towards which habitat and population management should be directed, respectively. Our results suggest that these distributions may change over long time periods in response to habitat modification and behavioral factors. Effective management of these biological units may require regular assessment of their distribution patterns, perhaps as frequently as every 10 years. Furthermore, the different factors related to the changes in elk distributions that we documented, suggests that

such changes cannot be predicted on the basis of substantial habitat change alone.

The prevalence of roads in all of our analyses reaffirms the importance of managing roads for maintaining effective elk habitat. Throughout our analyses and all scales examined, roads had the greatest influence over elk distributions. Elk responded negatively to year-round open roads and increased densities of year-round closed roads. Even though elk may have become less sensitive to open roads over the 2 studies, elk response to open roads remained negative.

Our study suggests a reevaluation of road closures as a management tool in maintaining quality elk habitat. Several studies and management guidelines recommend road closures to reduce elk vulnerability to hunting and the decrease elk avoidance of roads (Lyon et al. 1985, Leptich and Zager 1991, Moroz 1991, Cole et al. 1997). Year-round closed roads were the most common variable explaining long-term changes in elk distributions between our 2 studies, suggesting that road closures alone will not ameliorate the effects of roads on elk distributions. We recommend that the least amount of road construction as possible be planned to support management activities in elk habitat. Where road construction is required for management activities, we recommend that roads be designed with the intent of destroying and reseeding them after use.

ACKNOWLEDGMENTS

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visiting scholar fellowship to W. D. Edge. D. Turner provided assistance with statistical analyses. G. McWethy, C. Winnie, Z. K. Ma of the UM Wildlife Spatial Analysis Laboratory developed our vegetation classification maps. K. Weber assisted with data analysis and assembling the GIS database. Field assistants were R. Baxter, L. Clough, G. Edge, B. French, R. Pagel, R. Uchytil, and C. Yee. Telemetry flights during the first study were flown by W. Tubbs and D. Rozenkranz of Hamilton Aviation; W. Stewart of North Star Aviation was the pilot during the second study. Helicopter Wildlife Management assisted in capturing of elk during the second study. M. Wisdom and B. Johnson provided comments on an earlier draft of the manuscript. This paper is dedicated to the memory of Darrell Sall, BLM Resource Area Manager during both studies.

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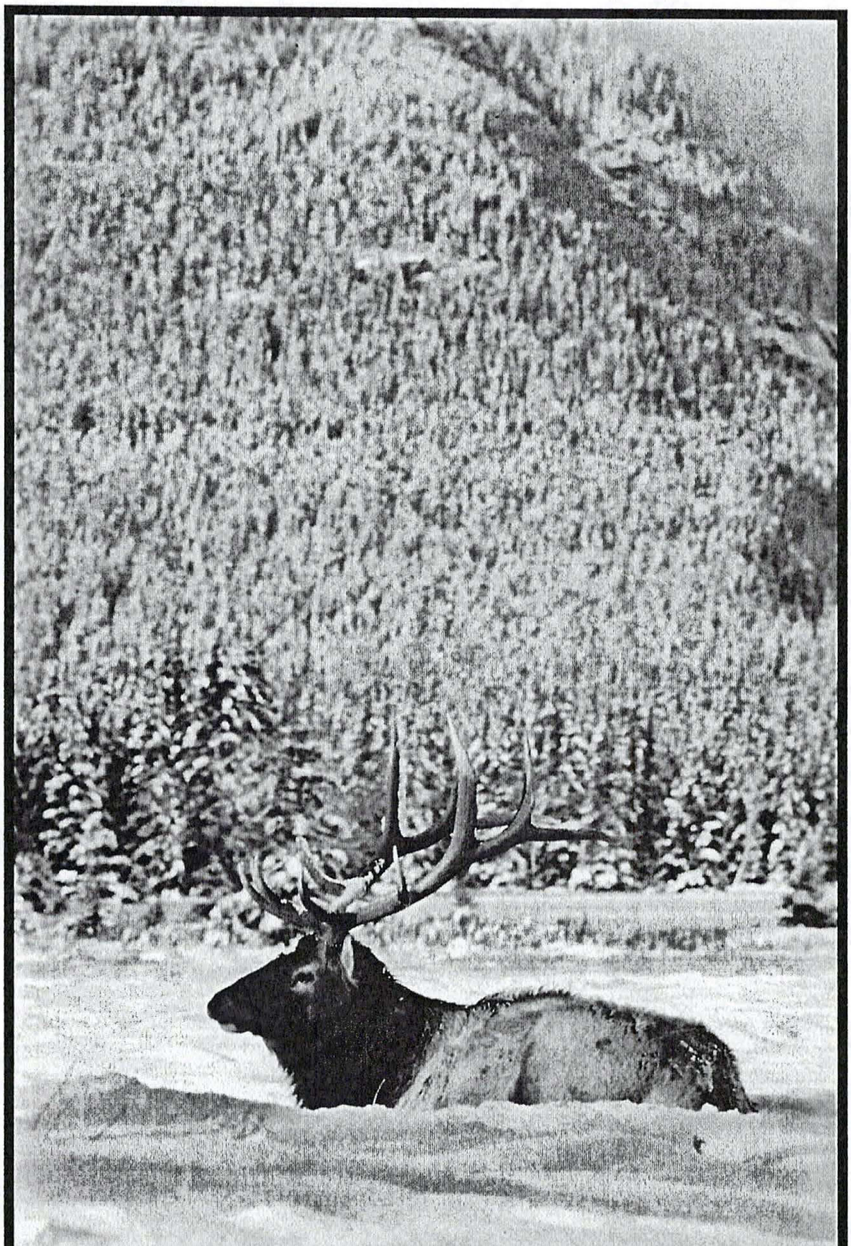
Chapter 3

ELK HABITAT SELECTION AT A SITE SPECIFIC SCALE



ELK HABITAT SELECTION AT A SITE SPECIFIC SCALE

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Abstract: I examined and compared, at a site specific scale, 1) pre-logging habitat use (1977-1980), 2) immediate post-logging habitat use (1981-1983), and 3) long-term post-logging habitat use (1993-1996) by elk in the Chamberlain Creek study area. A discriminant function analysis demonstrated that the three groups could be identified on the basis of changes in elk habitat use during the three time periods. However, the separations were not strong because the changes in habitat were less pronounced than the adjustments in habitat selection by elk. A second discriminant function analysis demonstrated that elk locations within each of the three groups could be differentiated from random locations. For each of the groups, and for all five seasons within groups, the average correct classification was greater than 80%. Over the years and in every season, elk have selected habitats distant from open roads. During the same time period, it appears that elk tolerance for closed roads has increased slightly, but most of the change is related to the summer season. Habitat selection changes also include a decline in use of closed canopy forest and an increase in use of open coniferous forest, except during the hunting season.

Keywords: elk, habitat selection, discriminant function

The primary objectives of the Chamberlain Creek study were to determine the effects of long-term forest fragmentation related to timber harvest on certain aspects of elk ecology and habitat use. Because of developments in research technology, specifically the improvements in

GIS and the availability of 30m Landsat data, it was possible to examine habitat selection patterns of free-ranging elk at several different landscape scales and to compare results based on elk location data from a previous study conducted in the same area. The data sets include elk locations from 1977-80 (pre-logging), 1981-83 (post-logging), and 1993-96. This latter period presumably represents the adjustment of elk to substantial habitat changes resulting from increased logging activity between 1983 and 1995 and to some relatively major changes in land management in the Blackfoot River drainage during this same period of time. This section reports one of several studies within the Chamberlain Creek research program examining the influence of forest fragmentation on vulnerability, habitat selection, and distribution of elk in Western Montana. Data analysis in this section examines and compares 1) prelogging habitat use at site specific landscape scale, 2) immediate postlogging habitat use at site specific landscape scale, and 3) longterm postlogging habitat use at site specific scale. Perceptive readers will notice changes in tense in various parts of this section. The analysis was conducted entirely by Lyon, but many of the difficult interpretations required consultation with Burcham and Marcum.

METHODS

Elk Location Data

Locations of radio-equipped elk were recorded at weekly intervals from May through November and twice weekly during the hunting seasons in the years 1977 to 1983 and 1993 through 1996 (Appendix A). Irregular observations were also available in some years for the December to April period. All observations were made from fixed wing aircraft, and about 56 percent of all sightings were visually confirmed. Locations were noted on USGS topographic

maps and recorded to the nearest 100 m UTM grid in database files. All elk locations were converted to arc/info point coverages. For the analyses presented here, three elk location point coverages were developed:

RELELK (real old) 1415 observations, 1977-1980

OLDELK (old) 1421 observations, 1981-1983

NEWELK (new) 2227 observations, 1993-1996

GIS Background Coverages

Relationships between elk and the available environment required the creation of several line and polygon coverages. The methods, sources, and availability of these coverages are fully described in another section of the Chamberlain Creek Final Report. The available coverages include: Roads: digitized from USGS 7.5' topographic maps, corrected and edited to indicate year of construction and status by year as 1) openyear around, 2) seasonally closed, 3) closed all year, 4) not traversable.

Vegetation: polygon coverages in arc/info were created through unsupervised classification and change comparisons among Landsat MSS digital coverages for 1973 and 1984 and Landsat TM digital coverages for 1984 and 1992; followed by ground-truth sampling. Three separate coverages were developed:

RELVEG representing vegetation about 1972

OLDVEG representing vegetation about 1984

NEWVEG based on TM image from 1992

Within each of these coverages, an initial polygon identification of relatively high

precision was attempted. At this level we had 23 identified vegetation classes. As the analysis developed, however, we discovered that many of these classes lacked real definition on the ground. As a result, the vegetation classes eventually used for analysis were collapsed into seven identified types:

V1 agriculture (01), cropland (02,03,04,06), foothills and parkland (05)

V2 shrubs: sagebrush (10), mesic upland shrub (08,09,11)

V3 broadleaf forest (13)

V4 conifer forest: spruce(14), lodgepole (15), Douglasfir (17), larch (18), mixed conifer (19)

V5 ponderosa pine forest and savanna (16), open Douglasfir (20)

V6 old clearcut with tall regeneration (21)

V7 wet meadows (22,23)

Site Specific Data Summary

Identification and summary of vegetation and road components associated with each elk location was accomplished within arc/info and MAYA (Glassy and Lyon 1989), a PC program written specifically for this purpose. In arc/info, the elk point coverage is overlaid on the road coverage, and the command NEAR produces a database file listing the distance to the nearest road. In this study I determined both the nearest open road and the nearest road of any kind. For most sampling points, the nearest road was seasonally or permanently closed.

In MAYA, the elk point coverage is overlaid on the vegetation polygon coverage and the program produces a database file listing the area of each vegetation type within a specified distance of the point. For this analysis I summarized the vegetation complexes and stand

structures available to elk in a sampling diameter circle of 750m around each recorded location. The sample frame thus examined includes 482 pixels (43.38 ha, 107.2 acres). Further calculations on these data produce two additional variables that identify the largest vegetation polygon available from the sample frame and express diversity as the number of different vegetation polygons available within the sample frame.

Analysis of Site Specific Habitat Selections

In addition to the 5,063 elk locations, I generated 3500 random locations for use in discriminant function analysis. Those random points that fell outside the background coverages for the study area were discarded. This left approximately 3200 points applicable to each of the three analysis groups: RELRAN, OLDRAN, and NEWRAN. These points were treated as identical to the databases for elk locations. They were used in sampling the road and vegetation data with arc/info and MAYA and have been assigned a season by numbering from 1 to 5 in sequence.

Correlation:

The initial exploration of these data was simply an examination of Pearson correlation among all variables. Correlation within the random samples, in particular, was considered to be a likely indicator of interpretation problems. Multiple correlations made it necessary to delete some variables from analysis.

Discriminant Function:

I used the discriminant function as an exploratory analysis tool to test two primary hypotheses: 1) that the three groups, RELELK, OLDELK, NEWELK could be identified on the basis of changes in elk habitat use during the three time periods, and 2) that elk locations within

each of the three groups could be differentiated from random locations. Within each of these hypotheses, I also tested for seasonal differences in habitat selection.

Results for the discriminant function are presented in two sections: Discriminant Function: Changes in Habitat Use, which relates to hypothesis 1; and Discriminant Function: Elk Selection versus Random Samples, which relates to hypothesis 2. It seems important to emphasize that these are indeed two different analyses even though the conclusions seem to approach identity.

RESULTS AND DISCUSSION

Correlation

In the initial examination of data, using only the random sample data, all possible combinations of Pearson correlation were calculated for the 7 vegetation variables (V1 to V7), 2 road variables (nearest open, nearest), and 3 landscape variables (diversity, largest patch, elevation).

Because the samples were so large, linear correlation as low as 0.03 was significant at P:0.05. Eliminating all significant intercorrelations would have effectively eliminated much of the available data. I therefore selected 0.30 as the arbitrary level at which correlation between variables was closely examined. At this level, only two variables were considered likely to cause troublesome decisions in interpretation of results.

Elevation was highly correlated with most of the vegetation variables as well as the cultural and landscape variables: sagebrush and pasture are low elevation, forests are mostly high, road density is highest in the forested areas, and diversity is greatest at low elevations because the largest patches occur in the higher elevation uncut forest. Because of these many

interrelationships, elevation was eliminated from further analysis.

V4 presents a somewhat more difficult consideration. Throughout all data sets, the coniferous forest (mostly lodgepole) was negatively correlated with V1 agricultural and V5 open coniferous (ponderosa savannah and open Douglas fir). V4 was also positively correlated with larger patch sizes and negatively correlated with diversity, the number of patches. Because these vegetation and landscape variables are so important to understanding elk habitat selection, no elimination of variables was considered possible. However, I did calculate a second set of Pearson correlation coefficients using only the elk location data. My assumption is that deviations from identity between the coefficients (random and elk) should suggest the degree to which habitat selections by elk are modified by habitat availability on the larger landscape. Appropriate Pearson coefficients are presented in Table 1.

Discussion

Interpretation of these relationships is most meaningful if the focus is on the differences between the random point sample and the elk sample rather than any specific interpretation of elk habitat selection. Correlation between V4 and V1 (coniferous forest vs agricultural) is negative in both the random sample and the elk locations. The differences among time periods are minor, and I conclude that elk are pretty much using these two types as they occur on the landscape.

Correlation between V4 and V5 (coniferous forest vs open coniferous), on the other hand, indicates a fairly major difference between random points and elk locations. In both samples, the presence of V4 negates the presence of V5, but the elk samples show an even stronger negative correlation. I interpret this to indicate that elk habitat sample frame selections are less likely to

Table 1.-Pearson correlation > .30 between V4 and other variables in random sample frames and elk location sample frames.

REL data	**V1**	**V5**	**DIvers**	**LArge**
V4 rand	-.633	-.416	-.340	.544
V4 elk	-.690	-.666	-.502	.557
OLD data	**V1**	**V5**	**DIvers**	**LArge**
V4 rand	-.665	-.445	-.424	.568
V4 elk	-.629	-.676	-.485	.504
NEW data	**V1**	**V5**	**DIvers**	**LArge**
V4 rand	-.657	-.462	-.396	.536
V4 elk	-.654	-.749	-.534	.613

include both V4 and V5 as components than are random samples.

V4 vs DI (coniferous forest vs diversity) is consistently negative and V4 vs LA (coniferous vs large patch) is consistently positive. This is entirely consistent with the observation that most large patches are coniferous, and that there is little difference between elk and random when V4 is present. Throughout the samples, however, the habitat selections by elk are less diverse than random samples when V4 is a component.

Discriminant Function: Changes in Habitat Use

All of the tests with the discriminant function were considered exploratory and most are not reported here in detail. The objective was to develop a subjective evaluation of the contributions of different habitat variables to habitat selection by elk in the three different time periods of the study and seasonally within those time periods. Because elk are highly adaptable habitat generalists, the level of precision possible with such models is not very high. Instead of concentrating on a precise habitat selection model, it seemed most important to examine the relationships among habitat variables within the three time periods and the relative changes in selections by elk as the environment was modified.

The vegetation classes V01 to V23 proved to have intercorrelations too complex for interpretation, and elevation seemed capable of masking any effect of several vegetation and landscape variables. SEX was also removed as a variable after it was recognized that the proportion of bulls in the NEWELK sample was far greater than the proportion in the RELELK and OLDELK samples. As a result, the eventual analyses utilized only the grouped vegetation variables, V1 to V7, two landscape variables, DIVR and LARG, and the two road variables

NEROD and NOROD.

The first attempt to discriminate among the three groups, RELELK, OLDELK, and NEWELK, correctly classified 57.0 percent of the observations. Discrimination between RELELK and OLDELK was 62.8 percent, and between OLDELK and NEWELK, 74.6 percent. This result was primarily useful in providing some further insight into agricultural management influences on elk habitat selection patterns in the three time periods. In the three-way separation, large patches, conifer forest and roads were the discriminating variables. However, discrimination between RELELK and OLDELK utilized reduced use of V2 (sagebrush, upland shrub) and V7 proved to be important in separating OLDELK and NEWELK.

We were willing to tentatively accept that shrubfields might have become less desirable in the post-logging OLDELK environment, but the appearance of V7 in the analysis was unexpected because V7 is such a minor component of the available environment. Closer examination revealed that V7 included all the open water detected in the landsat image. Sixty percent of this type proved to be the Blackfoot River, and the attraction for elk proved to be the refuge effect provided by riverside ranches on which animals could find complete protection from disturbance.

Because of these identified anomalies in the data, we elected to eliminate all locations influenced by the "refuge effect." This was relatively expensive in the number of observations lost for NEWELK data. The sample points used for final analysis include 1316 for RELELK, 1251 for OLDELK, and 1292 for NEWELK. We have also added a separate section to the Chamberlain report in which we discuss the influence of refuge areas on elk habitat selections, behavior, and management.

The revisited discriminant function, using 3859 observations, provided 53.9 percent correct classification for the three groups: RELELK, OLDELK, and NEWELK; and correctly classified 62.1 percent of the RELELK vs. OLDELK and 75.5 percent of the OLDELK vs. NEWELK samples. While providing no improvement in discrimination, the variables selected were far more consistent and meaningful. Basically, five variables provide the discriminating power in these separations, and four of the five are represented in linear progressions of means from RELELK to OLDELK to NEWELK (Table 2a).

Discussion:

The two vegetation variables, the two road variables, and the diversity variable all appear to describe an identical situation. Over the time period described in these data, elk habitat selections have tended to include less closed canopy forest and more open canopy forest while expressing greater tolerance of proximity to roads and increased fragmentation.

The variable LARG (largest patch) may not be meaningful in these data because elk habitat selections probably cannot be separated from the peculiarities of landscape description in the database. The base data for the vegetation coverages suggests these relationships are a function of limited availability rather than selections by elk. RELVEG, OLDVEG, and NEWVEG contain very few patches larger than 2000 ha, and the average size for large patches increases incrementally as the number of large patches declines (from 3139.3 ha (n=4) in RELVG to 3930.6 ha (n=3) in OLDVEG to 5569.2 ha (n=1) in NEWVEG).

The most important question, in any case, is whether these changes represent changes in the habitat selections made by elk or changes in the habitats available to elk. The means for random samples associated with the three time periods (Table 2b) reveal identical directional

Table 2a.--Means of the major discriminating variables in selections made by elk.

Variable	Relelk	Oldelk	Newelk
V4	385	380	290
V5	43	47	106
NOROD	1921	1907	1743
NEROD	353	266	219
DIVR	3.5	3.6	4.1
LARG	3382	4087	1853

Table 2b.--Means of the major elk habitat discriminating variables in random samples.

Variable	Relelk	Oldelk	Newelk
Means of random selections:			
V4	325	318	290
V5	54	60	75
NOROD	596	596	588
NEROD	350	329	294
DIVR	3.9	4.1	4.3
LARG	2620	2710	1816

changes for V4, V5, NOROD, NEROD, DIVR, and LARG as seen in the elk selection samples. Thus, over the time period described in these data, available elk habitat has tended to provide less closed canopy forest and more open canopy forest in an increasingly fragmented environment with increasing densities of closed roads. However, the distance to open roads apparently has not changed. In summary, I conclude that while the changes in the habitat were less pronounced than the adjustments in habitat selection by elk, there is indeed some evidence of greater elk tolerance for roads and increased fragmentation.

Seasonal Habitat Selection

Examination of these data within seasons did not materially improve the discrimination percentages but it did help to clarify some elk habitat selection patterns. Seasonal discrimination ranged from 48 to 55 percent correct classification for the three groups: RELELK, OLDELK, and NEWELK; and correctly classified 55-61 percent of the RELELK vs. OLDELK and 62-73 percent of the OLDELK vs. NEWELK samples. The variables selected were seemingly inconsistent, but when examined across all three groups do suggest reasonable interpretations. Table 3 presents the relevant data.

Discussion:

Calving: Selections during the calving season indicate increasingly diverse habitats with more agricultural components, more lowland shrub, and less conifer forest. Distances to roads decrease, indicating a possibly increasing tolerance.

Summer: Summer selections continue the increased agricultural component, but lowland shrub declines and open forest increases substantially. Distances to roads decrease, indicating an increased tolerance.

Table 3.--Means of the major elk habitat discriminating variables by season across groups.

Variable		Relelk		Oldelk		Newelk
CALVING:						
	V1	41	*	55		87
	DIVR	3.6	*	4.0		4.5
	V2	0.2		0.9	*	4.0
	V4	361		337	*	218
	NOROD	2024		2071	*	1608
	NEROD	247		224	*	146
SUMMER:						
	V1	54	*	40		84
	V2	2.1		1.6	*	0.6
	V5	36	*	49	*	134
	NOROD	1825	*	1911	*	1518
	NEROD	349	*	234		190
RUT:						
	V2	6.9		6.2	*	2.0
	V5	49	*	26	*	55
	DIVR	3.5		3.5	*	3.1
	NOROD	1995	*	1805	*	2176
	NEROD	416	*	300		280

Table 3 (cont.)

HUNTING SEASON:					
V1	28	*	31		35
V2	3.3	*	0.7	*	9.2
DIVR	3.4	*	3.2	*	3.6
NOROD	1999		1974	*	2133
NEROD	340		351	*	272
WINTER:					
V2	0.5		2.8	*	10.6
V4	359		334	*	223
V6	1.8	*	8.1	*	3.5
NOROD	1826	*	1548		1490

* An asterisk between group means indicated a variable selected in the discriminant function

Rut: Habitat during the rut includes an increased conifer component, a declining shrub component and increased distance from open roads with reduced distance to any road (closed).

Hunting season: Habitat selections during the hunting season indicate a long-term increase in agricultural and lowland shrub types along with an increased tolerance for any road (NEROD) at greater distance from open road (NOROD). Notice, however, that the OLDELK sample shows an increase in the any road distance and a major decline in lowland shrub. These changes are all consistent with avoidance of low elevation habitats and roads when first created (REL vs OLD) followed by greater tolerance for closed roads and recognition of some refuge effects associated with low elevation types (OLD vs NEW).

Winter: Winter habitat selections return to the continuing trends of increasing lowland shrub habitats and declining conifer cover with greater tolerance for open roads (although note that the mean distance to an open road is still 1.5 km). The jump in use of older clearcuts in the OLD period is difficult to interpret.

Discriminant Function: Elk Selection versus Random Samples

A second complete set of discriminant function analyses tested the identification of elk habitat selections versus random selections within the available habitat. For each of the temporal groups REL, OLD, NEW, and for all five seasons within these groups, the average correct classification was greater than 80 percent (Table 4). This high classification rate was an exciting indication that changes in habitat selection over time did take place but were somewhat obscured in discriminate analysis of temporal groups because of adjustment by elk to existing habitats.

Table 4.--Means of the major elk habitat discriminating variables by season across groups.

		Temporal Group	
Season and Variable	REL	OLD	NEW
YEARLONG:	81%	82%	78%
NOROD	1921*	1908*	1744*
NEROD	353*	266*	219*
V4	385*	380*	290
V5	43*	47	106*
V1	45*	45	73
CALVING:			
NOROD	2024*	2071*	1608*
NEROD	247*	224*	146*
V4	361*	337*	218
V5	69	78*	157*
V1	41	55*	87*
SUMMER:			
NOROD	1825*	1911*	1518*
NEROD	349*	234*	190*
V4	384*	382*	255
V5	36	49	134*
V1	54*	40	84

Table 4 (cont.)

RUT:				
	NOROD	1995*	1805*	2176*
	NEROD	416	300*	280*
	V4	384*	397*	376*
	V5	49	26	55
	V1	38	47	43*
HUNTING SEASON:				
	NOROD	1999*	1974*	2133*
	NEROD	340*	351*	272*
	V4	411*	408*	384*
	V5	32	38	43
	V1	28	31	35*
WINTER:				
	NOROD	1826*	1548*	1490*
	NEROD	283*	256*	245*
	V4	359*	334	223*
	V5	45	44*	113
	V1	76*	93	130

* An asterisk indicates variables that appeared within the first 5 steps of the stepwise discriminant function analysis.

Discussion:

Throughout all of the elk vs. random analyses, the first variable selected in stepwise discrimination was the distance to the nearest open road. And, for virtually every analysis, the within group correlation between NOROD and the canonical discriminant function was 0.90 or higher. Over the years and in every season, elk have selected habitats distant from open roads.

Of the variables entering the discriminant after NOROD, four appeared repeatedly and very often contributed substantially to discrimination. Within group means of these variables are listed in table 4, and, although the power of the discriminant was usually reached with three variables, an asterisk indicates whether the variable appeared in the first five steps of discrimination.

NOROD: During the three time periods of this study, the average distance to an open road declined from 1921 m to 1908 m to 1744 m. In every analysis the average distance to the nearest open road for elk locations averaged 3-4 times greater than the distance from a random point. The long-term decline in this distance is somewhat deceiving in that the changes were not uniform across seasons. Elk intolerance for open roads appears to have increased for the rut and hunt while declining in seasons that involve less threat.

NEROD: Closed roads apparently have far less influence on the behavior of for elk. In fact, the distance to the nearest road from an elk location was usually less than the average distance to the nearest road from a random point. The differences, however, were never very great, and interpretation does require a great deal of speculation. During calving season, for example, elk locations were 100 m nearer roads than random points, and this distance did increase slightly over time (Table 5). During the summer, however, elk tolerance for roads

Table 5.--Seasonal differences between average distance to the nearest road from elk locations versus random locations.

	Difference in meters, elk minus random				
Temporal Group	**Calving**	**Summer**	**Rut**	**Hunt**	**Winter**
REL	-109	-10	59	1	-52
OLD	-118	-108	-33	39	-63
NEW	-127	-102	-21	-31	-55

increased nearly 100 m from REL to OLD and NEW data sets. Most differences during the rut and hunt were under 40 m, and these were the only seasons in which elk were further than random points from the nearest roads. In winter, elk locations averaged 57 m nearer roads throughout all years of the study.

In attempting to evaluate these changes, it can be speculated that elk tolerance for closed roads has increased slightly over the years, but that most of the change is related to the summer season. It seems nearly as logical, however, to propose that since most of the increase in road densities over time took place on summer range, the changes in elk use may simply indicate a failure to respond. In other seasons there was little temporal change, and actual avoidance of closed roads (positive numbers in table 5) is confined to the breeding and hunting seasons.

V4 (Coniferous Forest): This habitat includes most of the closed canopy forest on the study area and occupies over half of the land surface. In the random sample frames, V4 declined from 67 to 66 to 60 percent of the area, but in elk habitat selections V4 declined from 80 to 79 to 60 percent. The decline occurred in all seasons but was predictably much lower during the rut and hunting season.

V5 (Savannah Forest): Although identified as open canopy forests, another defining characteristic of this habitat is that it occurs at lower elevations than V4. In the random sample frames, V5 increased from 11 to 12 to 16 percent; but elk use more than doubled, going from 9 to 10 to 22 percent of selected habitats. And, corresponding to the changes in use of V4, the seasonal increases in use of V5 were much less in the rut and hunting season.

V1 (agriculture, foothills): This habitat became a discriminating variable only seasonally, but it seems worth mentioning in this discussion because it rounds out the elk habitat sample

frames with 9, 9, and 15 percent. Random sample frames, over the same time periods, contained 12, 14 and 16 percent V1. The increased use of V1 by elk was seasonally least noticable in the rut and hunting season.

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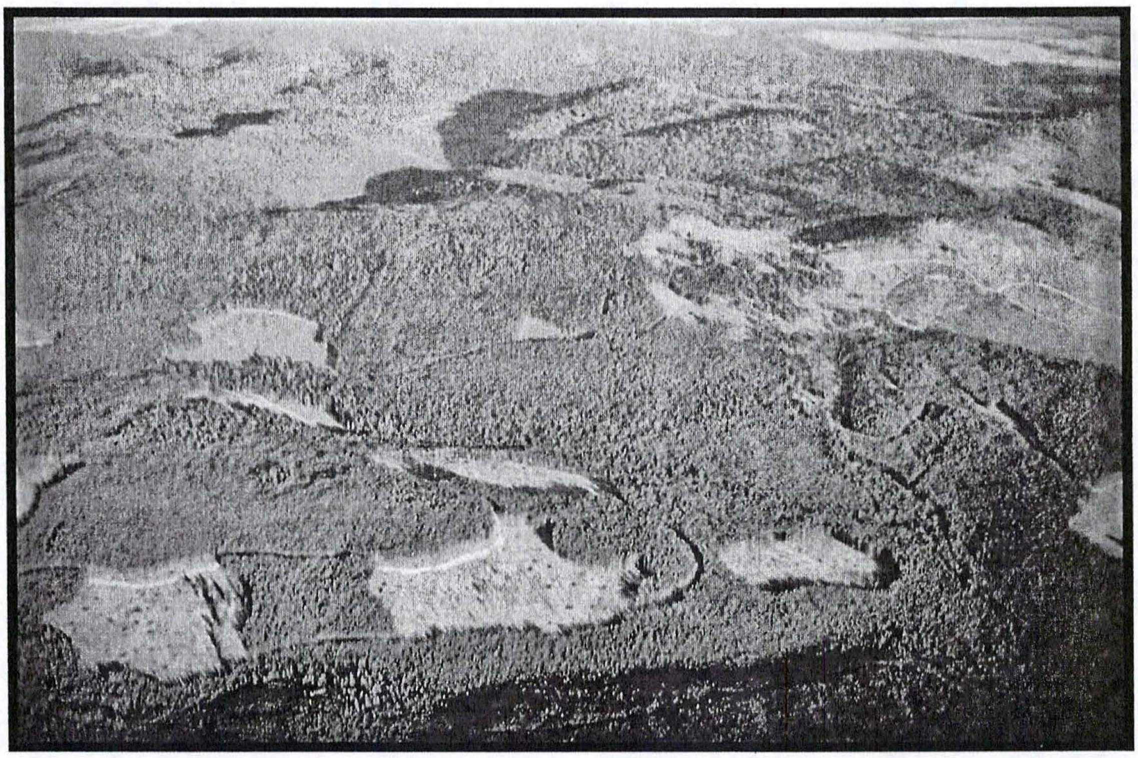
Chapter 4

LONG TERM CHANGES IN LANDSCAPE STRUCTURE WITHIN ELK HOME RANGES



LONG-TERM CHANGES IN LANDSCAPE STRUCTURE WITHIN ELK HOME RANGES

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Abstract: Timber harvest changes the structure of elk (*Cervus elaphus*) habitat by fragmenting the forest matrix. We examined differences in landscape metrics, produced by the program Fragstats, within seasonal 50% and 95% fixed kernal home ranges, for 2 western Montana elk herds, for the periods 1977-1983 and 1993-1996. Summer core areas tended to be more fragmented than the home range as a whole while those for hunting season were less. Results for year-long and rut core areas were not conclusive. Landscape metrics within seasonal core areas, generally, became more fragmented as did the habitat within the elk home ranges. Elk responded to fragmentation within their home ranges by using core areas with fragmentation values that were higher in summer and lower during the hunting season, than values for their entire home ranges. Generally, changes in fragmentation values within elk core areas reflected the fragmentation within their home ranges.

Key Words: *Cervus elaphus*, elk, fragmentation, Montana

Landscape ecology involves the study of landscape patterns, the interactions among patches within a landscape mosaic, and how these patterns and interactions change over time (McGarigal and Marks 1994). Wildlife ecologists have often assumed that important processes affecting wildlife populations operate at local spatial scales (Dunning et al. 1992), and most elk

habitat research has occurred on this scale. Only recently have wildlife ecologists begun to recognize that habitat variation and its effects on vertebrate populations occur at wide variety of spatial scales (Wiens 1989). Elk habitat preferences have been well documented over time and the importance of landscape configuration and composition has been recognized in various elk habitat models (Hillis et al. 1991, Thomas et al. 1979, Wisdom et al. 1986, Thomas et al. 1988). How changes in landscape pattern influence elk over time has been less well documented. We have conducted two elk studies represented by 3 time periods, within the same study area, and compared landscape metrics within home ranges and core areas of each period. The first study included the PRE (1977-1980) and OLD (1981-1983) periods, which represent elk ranges before and during the initiation of logging within the core of the study area (Marcum et al. 1984, Edge and Marcum 1985). The second study represents the NEW period (1993-1996) and represents a period in which elk had the opportunity to adapt to over 10 years of habitat modification.

Our objectives were to: 1) determine if landscape metrics within core areas of year-long and seasonal elk home ranges were different than those for the entire home range, 2) identify changes in landscape metrics within elk core areas between the old and new study periods, and 3) determine if any changes in landscape metrics within core areas paralleled the changes in landscape metrics for the entire home range. We hypothesized that values for selected landscape metrics within core areas would be the same as for the entire home range and that they would not change over time. Any changes that did appear in the values of selected landscape metrics within core areas over time, would parallel those changes for the entire home range.

STUDY AREA

The Chamberlain Creek study area is located 56 km east of Missoula, Montana in the northern Garnet Mountains (Fig. 1). Radio-collared elk use an area of about 210 km^2 that includes Chamberlain, Bear, Fish, Little Fish, Pearson, upper Wales, and North Fork of Elk Creeks, and Cap Wallace Gulch. The Blackfoot River borders the study area to the west and north.

Elevations range from approximately 1,115 m along lower Elk Creek and the Blackfoot River to 2,090 m at Chamberlain Mountain on the southeast side of the study area. Topography varies from steep, high-elevation, timbered basins in the upper portions of Pearson and Wales creek drainages to open level pastures and hayfields along the southern side of the Blackfoot River north of Blacktail Mountain, and adjacent to lower Elk Creek.

Weather of the study area is typified by cool, moist winters and hot, dry summers. Weather data were collected a Lubrecht Experimental Forest (elev. 1,250 m) at the western side of the study area. The average daily minimum temperature of -13.2 C occurs in January; the average daily maximum (28.2 C) occurs in July. Annual precipitation varies from 30 to 74 cm, more than two-thirds of which falls in winter and spring.

The forest overstory within the study area is predominately pole-size lodgepole pine (*Pinus contorta*) above 1,700 m on southerly aspects and above 1,550 m on northerly aspects. These stands resulted from extensive fires approximately 40, 70, and 90 years ago. Mature to old subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea englemannii*), western larch (*Larix occidentalis*), and Douglas-fir (*Pseudosuga menziesii*) are also found in isolated stands, predominately on north and east slopes. Subalpine fir and Englemann spruce may range down to

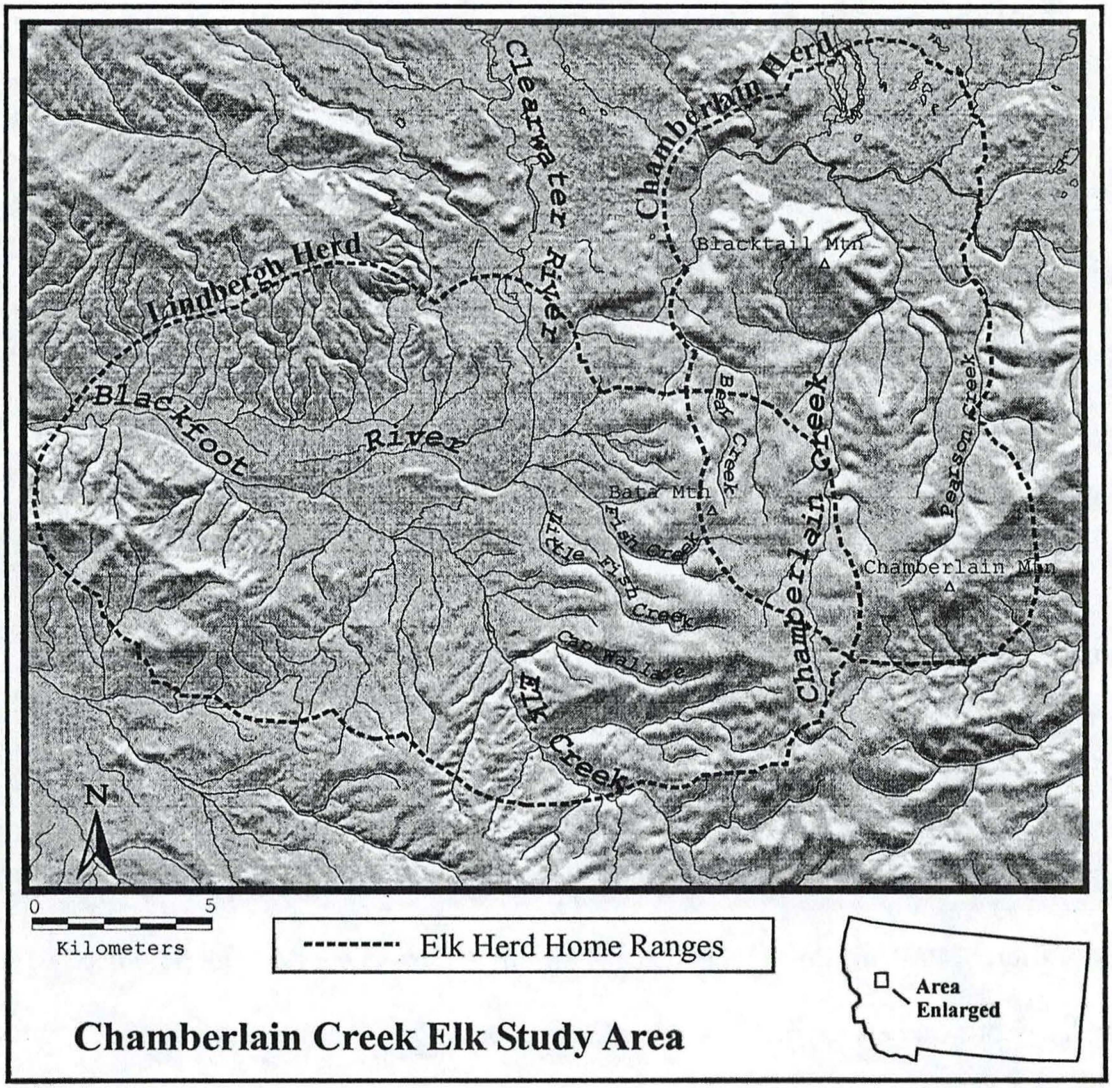

Figure 1. Study area and cumulative seasonal home ranges of Chamberlain and Lindbergh elk herds.

1,340 m in moist areas or stream bottoms. Douglas-fir dominates in nearly pure stands on dry west and south aspects below 1,700 m, while on north and east aspects, or locally moist sites, Douglas-fir occurs in mixed stands with western larch. Ponderosa pine (*Pinus ponderosa*) commonly occurs with Douglas-fir on low-elevation dry sites.

Non-forested vegetation occurs throughout the study area. Dry lower sites, such as open ridge tops and lower elevation slopes contain primarily bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and arrowleaf balsamroot (*Balsamorhiza sagittata*). Forbs become more abundant at higher moist sites. Hay meadows and pastures are planted with Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratensis*), orchardgrass (*Dactylis glomerata*), or alfalfa (*Medicago sativa*).

Two elk herds use the Chamberlain Creek study area (Edge et al. 1986). The Chamberlain Creek herd uses an area of approximately 82 km^2 within Chamberlain Creek, the upper portion of Pearson Creek and on Blacktail Mountain. The Lindbergh herd uses a 142 km^2 area adjacent to, and south and west of the Chamberlain Creek herd, including upper Chamberlain Creek, and Bear, Fish, Little Fish, and Elk creeks. Based on annual surveys, both herds contain approximately the same number of elk. Both elk herds are more widely dispersed during years of above-normal precipitation than during years of below-normal precipitation (Marcum and Scott 1985). During the OLD study, the Lindbergh herd began using agricultural lands on the west side of the study area during the fall in response to the availability of high-quality forage and security during the hunting season (Edge et al. 1984) and this use continued through the 1990s. During the NEW study, the Chamberlain Creek herd began using a similar refuge area north of Blacktail Mountain during the rut and hunting seasons. These refuge areas

are closed to hunting by the general public. Short-term elk movements (Edge and Marcum 1985) and home range fidelity (Edge et al. 1985) in response to logging disturbance, selection of feeding sites (Edge et al. 1988), habitat selection at micro and macro scales (Edge et al. 1987), and sexual segregation with respect to roads and logging disturbances (Marcum and Edge 1991) were described for the OLD study.

Upper elevations of the study area are managed largely by the Bureau of Land Management (BLM) and Plum Creek Timberlands, L.P. Logging and timber production has been, and continues to be, the predominant use of the study area. Logging was extensive on the flats and rolling hills adjacent to the Blackfoot River at the turn of the century. By 1950, extensive logging and associated road construction had occurred throughout the north, northwest, and west portions of the study area. Prior to the 1980s remnant and second growth timber was heavily logged throughout Bear Creek, Little Fish Creek, and lower Chamberlain Creek. Generally, the logging has been some form of partial cutting, with some clearcuts in Little Fish, and Bear Creeks. Large clearcuts were created during the late 1980's and 1990's in upper Bear Creek, Chamberlain Creek and East Fork of Chamberlain Creek. In 1994, a 500 ha wildfire burned logged and un-logged portions of Chamberlain and Pearson Creeks.

Prior to the start of the first Chamberlain Creek elk study, the central and upper portions of Chamberlain Creek were largely unroaded and unlogged. During the first study (1977–83), only a small proportion (< 5%) of the study area was logged primarily because of depressed timber prices. During the second study (1993–96), again, only minimal habitat change occurred. However, between studies extensive logging and roading occurred, especially in areas used by the Chamberlain Creek herd, largely in the form of clearcuts and seed-tree cuts in upper

Chamberlain Creek and the East Fork of Chamberlain Creek, and selective logging throughout the lower Chamberlain Creek drainage. Over the time period covered by this study, closed canopy coniferous forest cover (canopy cover ≥30%) decreased from 16,965 ha (67% of landscape) to 14,451 ha (58% of landscape). Much of this decrease in closed canopy coniferous forest can be accounted for by increases in open canopy coniferous forest (canopy cover < 30%), as a result of selective timber harvest. Decreases in closed canopy coniferous forest were accompanied by increases in open canopy coniferous forest (from 2,618 ha (10.4%) to 4,312 ha (17%)) and open grass-forb areas (from 3,245 ha (12.9%) to 4,384 ha (17.4%)). Within the Chamberlain elk herd home range, closed canopy coniferous forest decreased from 7,726 ha (76%) to 5,718 ha (56%), while open coniferous forest increased from 860 ha (8%) to 2,316 ha (23%) and open vegetation increased from 1,152 ha (11.3%)to 1,755 ha (17.2%). Within the Lindbergh elk herd home range, coniferous forest decreased from 12,152 ha (67%) to 10,955 ha (61%), while open coniferous forest increased from 1,804 ha (9.9%) to 2,454 ha (13.5%) and open vegetation increased from 2,301 ha (12.7%) to 3,100 ha (17.1%).

Private ranches surround the study area at the lower elevations and are managed for hay production and cattle and horse grazing. Timber production on these private ranches takes place on a relatively small scale in the form of selective harvests.

Hunting is the primary recreational use of these lands. Most of the study area falls within the Blackfoot Special Management Area. This cooperative agreement between landowners and Montana Department of Fish, Wildlife, and Parks restricts vehicle access to 16,565 ha to provide security for elk and a quality experience for hunters. Elk, white-tailed deer (*Odocoileus*

virginianus), mule deer (*O. hemionus*), moose (*Alces alces*) black bears (*Ursus americanus*), and mountain lions (*Felis concolor*) inhabit the area.

METHODS

During the first study, elk were live trapped using corral traps and fitted with radio transmitters encased in molded polyvinyl chloride (PVC) collars. For the second study, elk from the same two herds were captured using either Clover traps (Clover 1954, Thompson et al. 1988) or helicopter and net gun, and fitted with PVC and acrylonitrile butadiene styrene (ABS) plastic collars containing radio transmitters of 150-152 MHZ . Radio collared elk were located with a fixed wing aircraft: using 2 strut-mounted "H" antennas for the first study and a belly mounted yagi antenna for the second study. Elk were located weekly from mid May through late October and twice weekly through the general hunting season (which runs 5 weeks, ending the Sunday after Thanksgiving Day). Elk locations were plotted to the nearest 100 m using Universal Transverse Mercator grid coordinates. Seasons for analysis were summer (June 16 - August 31), rut (September 1 - start of hunting season), hunting season (5 weeks ending the Sunday after Thanksgiving), and year-long (all seasonal locations combined). Only locations female elk of the Lindbergh or Chamberlain herds were used for this study.

A geographic information system (GIS) formed the basis of our data analysis. We used PC ARC/INFO to characterize vegetation types and intersect elk home range polygons. We used Landsat Thematic Mapper (TM) scenes from 1992, 1984, and Multi-spectral Scanner (MSS) scenes from 1983 and 1973 to produce the needed digital vegetation coverages for 3 time periods: pre-logging represented by the period from 1977-1980 (PRE); logging and immediately

post logging, represented by the period from 1981-1983 (OLD); and the period from 1993-1996 which represents the adjustment of elk to long term logging activity in the area (NEW). Vegetation polygons were first classified by an unsupervised classification and 242 sites were ground-truthed during the summer of 1994. Using ground truth data, the University of Montana Wildlife Spatial Analysis Laboratory produced a supervised classification with 23 vegetation types using methods similar to those described by Hart (1994). For our analyzes, we grouped these 23 vegetation types into 7 classes: agricultural and cropland (V1), sagebrush and mesic upland shrub (V2), deciduous forest (V3), closed canopy coniferous forest (canopy cover ≥ 30%; V4), open canopy coniferous forest (canopy cover < 30%; V5), old clearcuts with sapling regeneration (V6), and wet meadows (V7).

The historical scenes were created by retaining unchanged vegetation data from the 1992 TM scene, and using change detection analyses between the 1992 TM and 1984 TM scenes and between the 1983 MSS and 1973 MSS scenes. For areas that did not change, vegetation information from the 1992 map was used for continuity between the two time periods. For the areas that did change, vegetation information from the older scene was inserted. For example, to produce the 1984 vegetation map, polygons from the 1992 vegetation map were used for areas that did not change. For those areas where vegetation did change, as indicated by the change detection performed between the 1992 and 1984 TM scenes, vegetation information from the 1984 scene were inserted, and verified by comparisons with historical aerial photographs. The same process was used to create the 1973 vegetation map (pre-logging) from the 1984 map and a change detection between 1983 and 1973 scenes. This process resulted in vegetation maps representing the 3 periods of interest to this study.

Fixed kernal home ranges were calculated using the program Ranges V (Worton 1989, Kenward and Hodder 1996, Seaman and Powell 1996). Home ranges for each herd were calculated using a 50X50 grid and a smoothing factor calculated with SD/Sixth root N. A home range boundary, represented by the 95% isopleth, was calculated for three time periods: PRE, OLD, and NEW. A union of these 3 home ranges for the Chamberlain and Lindbergh herds was used to represent their home ranges. Core areas for each herd were represented by seasonal 50% isopleths. Year-long, summer, rut, and hunting season cores were examined (Appendix B). Cores that were centered on private land refuge areas were eliminated from analysis. Year-long and summer cores were calculated for each year of study. For the hunting season and rut, cumulative cores for each of the 3 time periods were calculated because sample sizes for individual years were < 35 locations. The coordinates for the home range polygon boundaries were then converted to GIS layers to be intersected with the vegetation maps. Polygons representing core areas of elk home ranges were then given a 100 m buffer and intersected with appropriate vegetation maps for the time period.

Home range cores large enough to provide meaningful landscape analyses were summarized. Representative landscape metrics could not be produced from small areas with few patches, so only larger cores, those ≥ 100 ha, were summarized. Landscape metrics for these cores were produced using the program Fragstats (McGarigal and Marks 1994). Landscape metrics for 95% isopleths were produced for each herd home range at each of the 3 time periods for comparative purposes. Comparisons of landscape metrics between time periods were made using T-tests where sample sizes permitted (year-long and summer). Because core areas and home ranges varied in size, only metrics standardized for area were chosen, so that results would

be comparable. Of these, the metrics chosen for summarizing and comparing elk home ranges and core areas were those deemed to be most ecologically meaningful to elk (McGarigal and Marks 1994). Selected landscape metrics are defined below (taken from McGarigal and Marks 1994):

PATCH DENSITY (PD) - PD equals the number of patches in the landscape divided by the landscape area, multiplied by 10,000 and 100 (to convert to 100 hectares).

MEAN PATCH SIZE (MPS) - MPS equals the total landscape area (m^2), divided by the total number of patches, divided by 10,000 (to convert to hectares).

EDGE DENSITY (ED) - ED equals the sum of lengths (m) of all edge segments in the landscape, divided by the total landscape area (m^2), multiplied by 10,000 (to convert to hectares). ED does not include landscape border as edge.

CONTRAST-WEIGHTED EDGE DENSITY (CWED) - CWED equals the sum of lengths (m) of all edge segments in the landscape multiplied by their corresponding contrast weight, divided by the total landscape area (m^2), multiplied by 10,000 (to convert to hectares). Contrast weights are provided in Table 1.

MODIFIED SIMPSON'S DIVERSITY INDEX (MSDI) - MSDI equals minus the logarithm of the sum, across all patch types, of the proportional abundance of each patch type squared.

PATCH RICHNESS DENSITY (PRD) - PRD equals the number of different patch types present within the landscape boundary, divided by the total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares).

Table 1. Contrast weight values for pairs of vegetation classes, used for calculating contrast-weighted edge density. Vegetation classes are: agricultural and cropland (V1), sagebrush and mesic upland shrubs (V2), deciduous forest (V3), closed canopy coniferous forest (V4), open ponderosa pine and Douglas-fir forest (V5) old clearcuts with sapling regeneration (V6), and wet meadows (V7).

Vegetation Classes	Contrast Weight Value
V1/V2	0.0
V1/V3	0.7
V1/V4	1.0
V1/V5	0.5
V1/V6	0.7
V1/V7	0.1
V2/V3	0.7
V2/V4	1.0
V2/V5	0.5
V2/V6	0.7
V2/V7	0.1
V3/V4	0.5
V3/V5	0.3
V3/V6	0.3
V3/V7	0.9
V4/V5	0.5
V4/V6	0.3
V4/V7	1.0
V5/V6	0.7
V5/V7	0.5
V6/V7	0.1

<u>INTERSPERSION AND JUXTAPOSITION INDEX (IJ)</u> - IJ equals minus the sum of the length (m) of each unique edge type divided by the total landscape edge (m), multiplied by the logarithm of the same quantity, summed over each unique edge type; divided by the logarithm of the number of patch types times the number of patch types minus 1 divided by 2; multiplied by 100 (to convert to a percentage). In other words, the observed interspersion over the maximum possible interspersion for the given number of patch types.

<u>CONTAGION (CON)</u> - CON equals minus the sum of the proportional abundance of each patch type multiplied by the number of adjacencies between cells of that patch type and all other patch types, multiplied by the logarithm of the same quantity, summed over each patch type; divided by 2 times the logarithm of the number of patch types; multiplied by 100 (to convert to a percentage). In other words, the observed contagion over the maximum possible contagion for the given number of patch types.

<u>CONIFEROUS FOREST CORE AREA PERCENT OF LANDSCAPE (CV4)</u> - CV4 equals the sum of the core area of each patch (m^2) of coniferous forest (V4), divided by the total landscape area (m^2), multiplied by 100 (to convert to a percentage); In other words, CV4 is the percentage of the landscape comprised of coniferous forest core area. Core area was defined as the patch area 100 m from edge.

RESULTS

During the first study we obtained 2,837 radio location from 66 female elk between mid-May and early December, 1977 through 1983. We obtained 2,021 locations from 39 female elk

between mid-May and early December, 1993 through 1996 for the second study (Appendix A). Visual confirmations of elk at telemetry locations were made 51% of the time for the first study and 62% of the time for the second study. Table 2 shows the sample of elk locations for each herd and season. Fixed kernal home ranges and cores were generated from these locations.

Generally, sample sizes of year-long and summer elk locations were great enough to produce meaningful home ranges and core areas for landscape analyses (Table 3). For seasons with fewer than 35 seasonal locations within a time period (PRE, OLD, NEW) samples were pooled to construct home ranges for each period. This was necessary for hunting season and rut locations.

Within 95% fixed kernal home ranges, landscape metrics PATCH DENSITY, EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX, all increased from the past to present study. MEAN PATCH SIZE, CONTAGION, CONIFEROUS FOREST CORE AREA all decreased, while PATCH RICHNESS DENSITY and INTERSPERSION AND JUXTAPOSITION INDEX remained relatively stable. These trends were consistent within both herd home ranges.

Year-long

Year-long elk locations included those from calving season (15 May-15 June), summer, the rut, and hunting season, providing the largest sample sizes (Table 2) and the most core areas for analysis (Table 3). Large sample sizes were possible because all seasonal locations for each herd were combined. Three Chamberlain core areas and 4 Lindbergh core areas were eliminated from analysis because they fell within private land refuge areas, and not within the managed forest environment. Samples were adequate to create cores for each year of the study for the

Table 2. Sample sizes of seasonal and year-long cow elk locations for the Chamberlain and Lindbergh elk herds, by year.

	Chamberlain Herd				Lindbergh Herd			
Year	**Year**	**Summer**	**Rut**	**Hunt**	**Year**	**Summer**	**Rut**	**Hunt**
1977	80	24	32	16	99	30	40	20
1978	165	77	42	24	194	87	67	25
1979	127	52	35	20	208	100	55	32
1980	214	89	57	46	197	84	56	33
1981	274	111	84	37	151	51	46	27
1982	198	79	49	28	272	87	79	59
1983	162	61	39	36	265	97	80	46
1993	198	87	54	55	27	11	7	8
1994	197	83	55	40	157	68	42	30
1995	239	93	54	59	224	81	56	64
1996	342	126	94	72	243	87	64	53

Table 3. Numbers of core areas available for analysis by herd, season and time period. PRE = 1977-1980; OLD = 1981-1983 or 1977-1983 if no "PRE" core exists; NEW = 1993-1996.

		PRE	OLD	NEW
Chamberlain	**Year-long**	7	6	8
	Summer	-	6	7
	Rut	-	4	1
	Hunt	-	2	1
Lindbergh	**Year-long**	-	8	2
	Summer	-	6	4
	Rut	-	2	0
	Hunt	-	2	1

Chamberlain herd, permitting 7 cores to be analyzed for the PRE period, 6 for the OLD period, and 8 for the NEW. For the Lindbergh herd, 8 cores were analyzed for the OLD time period and only 2 for the NEW.

Differences between home range and core area metrics

Chamberlain herd. With the exception of PATCH RICHNESS DENSITY, metrics of year-long core areas could not be separated from metrics of the entire year-long home range ($P \leq 0.05$) (Table 4). PATCH RICHNESS DENSITY within core areas was higher than within home ranges for all periods of study ($P \leq 0.05$). Means for the selected landscape metrics are presented in Table 5.

Lindbergh herd. Landscape metrics within OLD Lindbergh cores were generally different than those for the entire home range ($P \leq 0.05$), while NEW Lindbergh cores were generally inseparable from home range values ($P \leq 0.05$) (Table 4). OLD cores had lower values for EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX, and higher values for CONTAGION and CONIFEROUS FOREST CORE AREA than the entire study area ($P \leq 0.05$). NEW core metrics could not be separated from those of the home range with the exception of INTERSPERSION AND JUXTAPOSITION INDEX which was higher within cores than within the home range ($P \leq 0.05$). Means for the selected landscape metrics are presented in Table 6.

Changes in core area metrics between old and new studies

Chamberlain herd Landscape metrics within PRE, OLD, and NEW year-long core areas could not be separated from one another ($P \leq 0.05$)(Table 7). Means for the selected landscape metrics are presented in Table 5.

Table 4. Differences between selected landscape metrics within elk core areas and the entire elk home range for Chamberlain (C) and Lindbergh (L) elk herds, for year-long (Y) and rut (R) core areas, during the OLD (O) and NEW (N) time periods. See Table 1 or text for variable names.

	CY-O	CY-N	CR-O	CR-N	LY-O	LY-N	LR-O	LR-N
Greater within core area than	PRD	PRD	PRD	MPS	CON	IJ	PRD	?
within home range				PRD	CV4		IJ	
				IJ			CON	
				CV4			CV4	
Same within core area as within	PD	PD	PD	CON	MPS	MPS	PD	?
home range	MPS	MPS	MPS		PRD	ED	MPS	
	ED	ED	ED		IJ	CWE		
	CWE	CWE	CWE			D		
	D	D	D			MSD		
	MSDI	MSDI	MSDI			I		
	IJ	IJ	IJ			PRD		
	CON	CON	CON			CON		
	CV4	CV4	CV4			CV4		
Less within core area than				ED	ED		ED	?
within home range				CWE	CWE		CWE	
				D	D		D	
				MSDI	MSD		MSD	
					I		I	

Table 5. Mean values for landscape metrics within year-long and rut, OLD (1977-1983) and NEW (1993-1996), Chamberlain elk herd core areas.

	Year-long		Rut	
	OLD	**NEW**	**OLD**	**NEW**
Patch Density (#/100 ha)	2.5	4.2	2.45	0.54
Mean Patch Size (ha)	76.9	37.8	74.5	185.2
Edge Density (m/ha)	25.6	47.8	26.6	14.2
Contrast-Weighted Edge Density (m/ha)	21.0	26.3	20.5	9.0
Modified Simpson's Diversity Index	0.36	0.74	0.43	0.49
Patch Richness Density (#/100 ha)	1.00	0.88	0.73	0.27
Interspersion and Juxtaposition(%)	50.8	63.8	54.7	81.7
Contagion (%)	75.5	55.4	72.1	65.6
Coniferous Forest Core (% of Landscape)	56.1	32.8	50.9	61.0

Table 6. Mean values for landscape metrics within year-long and rut, OLD (1977-1983) and NEW (1993-1996), Lindbergh elk herd core areas.

	Year-long		Rut	
	OLD	**NEW**	**OLD**	**NEW**
Patch Density (#/100 ha)	?	?	1.98	?
Mean Patch Size (ha)	62.63	32.95	51.2	?
Edge Density (m/ha)	19.54	44.35	50.5	?
Contrast-Weighted Edge Density (m/ha)	11.21	23.95	15.8	?
Modified Simpson's Diversity Index	0.28	0.94	0.34	?
Patch Richness Density (#/100 ha)	0.61	0.29	0.28	?
Interspersion and Juxtaposition(%)	63.36	80.85*	63.7	?
Contagion (%)	80.65	53.3	76.9	?
Coniferous Forest Core (% of Landscape)	66.2	35.3	66.6	?

* Denotes significant difference from OLD to NEW time periods ($P \leq 0.05$)

Table 7. Changes in selected landscape metrics within year-long and rut elk core areas between the OLD (1977-1983) and NEW (1993-1996) time periods. See Table 1 or text for variable names.

	Chamberlain Year-long	Chamberlain Rut	Lindbergh Year-long	Lindbergh Rut
Metrics within core areas that increased from OLD to NEW study periods			IJ	?
Metrics within core areas which did not change from OLD to NEW study	PD, MPS, ED, CWED, MSDI, PRD, IJ, CON, CV4	PD, MPS, ED, CWED, MSDI, PRD, IJ, CON, CV4	MPS, ED, CWED, MSDI, PRD, CON, CV4	?
Metrics within core areas that decreased from OLD to NEW study periods				?

Lindbergh herd Landscape metrics within OLD, and NEW year-long core areas could not be separated from one another ($P \leq 0.05$) with the exception of INTERSPERSION AND JUXTAPOSITION INDEX which was greater within core areas during the NEW study period than the OLD study period ($P \leq 0.05$)(Table 7). Means for the selected landscape metrics are presented in Table 6.

Changes in core area metrics, relative to changes in home range metrics

Chamberlain herd. Changes within year-long core areas metrics could not be detected and did not follow the trends seen within landscape metrics for the elk home ranges.

Lindbergh herd. INTERSPERSION AND JUXTAPOSITION INDEX showed the only detectable change in landscape metrics for the Lindbergh herd. INTERSPERSION AND JUXTAPOSITION INDEX increased from the OLD to NEW study periods while remaining constant within the Lindbergh home range as a whole.

Summer

Summer sample sizes of elk locations were larger than those of any other single season, due to the length of this season (June 15 - August 31). As for the year-long analyses, core areas could be created for each year. No summer cores for either herd fell within private land refuge areas. For the Chamberlain herd, 6 cores were analyzed from the OLD time period and 7 from the NEW, while 6 OLD and 4 NEW cores were analyzed for the Lindbergh herd.

Differences between home range and core area metrics

Chamberlain herd. Seven of the 9 landscape metrics for Chamberlain summer core areas were the same as those within the home range during the OLD study period ($P \leq 0.05$), while only 4 of the 9 were the same during the NEW study ($P \leq 0.05$)(Table 8). Within OLD summer cores,

Table 8. Differences between selected landscape metrics within elk core areas and the entire elk home range for Chamberlain (C) and Lindbergh (L) elk herds, for summer (S) and hunting season (H) core areas, during the OLD (O) and NEW (N) time periods. See Table 1 or text for variable names.

	CS-O	CS-N	CH-O	CH-N	LS-O	LS-N	LH-O	LH-N
Greater within core area than	PRD	PD	MPS	MPS	PRD	ED	PRD	MPS
within home range		ED	PRD	PRD	CON	PRD	CON	PRD
		PRD	CON	CON	CV4		CV4	CON
			CV4	CV4				CV4
Same within core area as within	PD	CWED	IJ		PD	PD	PD	
home range	ED	MSDI			MPS	MSDI	MPS	
	CWED	IJ			IJ	IJ	IJ	
	MSDI							
	IJ							
	CON							
	CV4							
Less within core area than	MPS	MPS	PD	PD	ED	MPS	ED	PD
within home range		CON	ED	ED	MSDI	CON	CWED	ED
		CV4				CV4	MSDI	CWED
			CWED	CWED				MSDI
			MSDI	MSDI				IJ
				IJ				

PATCH RICHNESS DENSITY was greater ($P \leq 0.05$) and MEAN PATCH SIZE was less than ($P \leq 0.05$) values for these metrics within the home range. During the NEW study period, cores showed higher PATCH DENSITY, EDGE DENSITY, PATCH RICHNESS DENSITY and lower MEAN PATCH SIZE and CONIFEROUS FOREST CORE AREA than the entire home range ($P \leq 0.05$).Means for the selected landscape metrics are presented in Table 9.

Lindbergh herd. Landscape metrics within summer core areas for the Lindbergh herd were the same as for the home range in only 3 cases for both the OLD and NEW study periods ($P \leq 0.05$) (Table 8). PATCH DENSITY and INTERSPERSION AND JUXTAPOSITION INDEX had similar values within cores and home ranges during both study periods ($P \leq 0.05$), while MEAN PATCH SIZE was the same during the OLD study and MODIFIED SIMPSON'S DIVERSITY INDEX was the same during the NEW study ($P \leq 0.05$). During the OLD study, cores had higher PATCH RICHNESS DENSITY, CONTAGION, and CONIFEROUS FOREST CORE AREA than home ranges and lower EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, and MODIFIED SIMPSON'S DIVERSITY INDEX ($P \leq 0.05$). During the NEW study period, core areas had higher EDGE DENSITY ($P \leq 0.1$), CONTRAST-WEIGHTED EDGE DENSITY, and PATCH RICHNESS DENSITY than the home range, and lower MEAN PATCH SIZE, CONTAGION, and CONIFEROUS FOREST CORE AREA ($P \leq 0.05$). Means for the selected landscape metrics are presented in Table 10.

Changes in core area metrics between old and new studies

Chamberlain herd. Most landscape metrics within core areas did not change from the OLD to NEW time periods for the Chamberlain herd (Table 11). PATCH DENSITY was

Table 9. Mean values for landscape metrics within summer and hunting season, OLD (1977-1983) and NEW (1993-1996), Chamberlain elk herd core areas.

	Summer		Hunt	
	OLD	**NEW**	**OLD**	**NEW**
Patch Density (#/100 ha)	3.033	5.414*	0.605	0.621
Mean Patch Size (ha)	28.32	19.51*	184	161
Edge Density (m/ha)	34.45	60.1	2.75	11.2
Contrast-Weighted Edge Density (m/ha)	30.27	30.42	1.78	6.3
Modified Simpson's Diversity Index	0.499	0.804	0.021	0.278
Patch Richness Density (#/100 ha)	0.917	1.484	0.355	0.373
Interspersion and Juxtaposition(%)	79.08	53.24	61.4	33.3
Contagion (%)	65.84	54.17	95.5	76.6
Coniferous Forest Core (% of Landscape)	40.6	13.19	86.05	72

* Denotes significant difference from OLD to NEW time periods ($P \leq 0.05$)

Table 10. Mean values for landscape metrics within summer and hunting season, OLD (1977-1983) and NEW (1993-1996), Lindbergh elk herd core areas.

	Summer		Hunt	
	OLD	**NEW**	**OLD**	**NEW**
Patch Density (#/100 ha)	1.9	3.6	2.2	1.1
Mean Patch Size (ha)	48.1	28.3*	47	93.0
Edge Density (m/ha)	19.5	54.9*	22.4	6.1
Contrast-Weighted Edge Density (m/ha)	10.8	31.8*	12.5	3.1
Modified Simpson's Diversity Index	0.26	1.03*	0.27	0.05
Patch Richness Density (#/100 ha)	0.41	0.55	0.54	0.65
Interspersion and Juxtaposition(%)	63.7	66.5	61.9	41.3
Contagion (%)	80.4	51.7*	80.0	94.0
Coniferous Forest Core (% of Landscape)	70.6	25.2*	68.7	81.9

* Denotes significant difference from OLD to NEW time periods ($P \leq 0.05$)

Table 11. Changes in selected landscape metrics within summer and hunting season core areas between the OLD (1977-1983) and NEW (1993-1996) time periods. See Table 1 or text for variable names.

	Chamberlain Summer	**Chamberlain Hunt**	**Lindbergh Summer**	**Lindbergh Hunt**
Metrics within core areas that increased from old to new study periods	PD	ED, CWED, MSDI	ED, CWED, MSDI	MPS, CON, CV4
Metrics within core areas which did not change from old to new study	ED, CWED, MSDI, PRD, IJ, CON	PD, MPS, PRD	PD, PRD, IJ	PRD
Metrics within core areas that decreased from old to new study periods	MPS, CV4	IJ, CON, CV4	MPS, CON, CV4	PD, ED, CWED, MSDI, IJ

greater within core areas during the NEW than during the OLD study ($P \leq 0.06$). MEAN PATCH SIZE was lower within NEW cores than within OLD cores ($P \leq 0.05$). Means for the selected landscape metrics are presented in Table 9.

Lindbergh herd. Most landscape metrics within Lindbergh summer cores changed from the OLD to the NEW study (Table 11). EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, and MODIFIED SIMPSON'S DIVERSITY INDEX all increased within cores from the OLD to NEW studies, while MEAN PATCH SIZE, CONTAGION, and CONIFEROUS FOREST CORE AREA decreased. Means for the selected landscape metrics are presented in Table 10.

Changes in core area metrics, relative to changes in home range metrics

Chamberlain herd. Only 2 metrics showed significant changes ($P \leq 0.05$)within summer cores from the OLD to NEW study periods, and these changed in directions that paralleled changes in these metrics within the entire home range. Although not statistically significant, other changes within core metrics paralleled the changes found within home ranges.

Lindbergh herd. As with the Chamberlain herd, when landscape metrics within core areas changed between OLD and NEW study periods, they paralleled changes within the entire home range. PATCH DENSITY showed the same trend, although the change within this core metric from the OLD to NEW periods was not significant.

Rut

The shorter length of this season (September 1 - start of general rifle season) did not allow adequate sample sizes to create core areas for each year of study. "Lumped" cores were created for each time period (OLD, and NEW). Two Lindbergh rut core areas were eliminated from analysis because they fell within private land refuge. Four OLD and 1 NEW cores were

analyzed for the Chamberlain herd while 2 OLD cores and no NEW cores were analyzed for the Lindbergh herd.

Differences between home range and core area metrics

Chamberlain herd. Values for all landscape metrics within the 4 Chamberlain rut core areas from the OLD time period vary greatly and cannot be separated from those of home ranges (Table 4). During the NEW study period, core areas had higher values for MEAN PATCH SIZE, INTERSPERSION AND JUXTAPOSITION INDEX, and CONIFEROUS FOREST CORE AREA and lower values for PATCH DENSITY, EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, and MODIFIED SIMPSON'S DIVERSITY INDEX than the home range. Means for the selected landscape metrics are presented in Table 5.

Lindbergh herd. No rut core areas were available for analysis during the NEW time period. During the OLD study, PATCH RICHNESS DENSITY, INTERSPERSION AND JUXTAPOSITION INDEX, CONTAGION, and CONIFEROUS FOREST CORE AREA were higher within cores than the home range, while EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, and MODIFIED SIMPSON'S DIVERSITY INDEX were lower (Table 4). PATCH DENSITY, and MEAN PATCH SIZE within OLD, rut, core areas could not be separated from the values from the home range. Means for the selected landscape metrics are presented in Table 6.

Changes in core area metrics between old and new studies

Chamberlain herd. Generally, no difference could be detected between OLD and NEW core area metrics, largely due to great variability in the values of landscape metrics within OLD core areas (Table 7). Means for the selected landscape metrics are presented in Table 5.

Lindbergh herd. Since no rut cores were available for analysis during the new study, no comparison of metrics between old and new cores was possible (Table 7). Means for the selected landscape metrics are presented in Table 6.

Changes in core area metrics, relative to changes in home range metrics

Changes in core area metrics within core areas could not be detected for either herd, therefore, comparisons of those changes to changes within home ranges was not possible.

Hunting Season

The shorter length of this season (5 weeks), despite the fact that two telemetry flights were attempted per week, did not allow adequate sample sizes to create core areas for each year of study. "Lumped" cores were created for each time period (OLD, and NEW), as they were for rut analyses. One Chamberlain and 2 Lindbergh hunting season core areas were eliminated from analysis because they fell within private land refuge. Two OLD and 1 NEW hunting season cores were analyzed for both the Chamberlain herd and Lindbergh herds.

Differences between home range and core area metrics

Chamberlain herd. Values for landscape metrics within Chamberlain hunting season core areas were distinctly different than those for the home range (Table 8). Core areas had much higher values for MEAN PATCH SIZE, PATCH RICHNESS DENSITY, CONTAGION, and CONIFEROUS FOREST CORE AREA, and much lower values for PATCH DENSITY, EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX than the home range for both study periods. INTERSPERSION AND JUXTAPOSITION INDEX values within cores were similar to that for the home range during

the OLD study but much lower than the home range during the NEW study. Means for the selected landscape metrics are presented in Table 9.

Lindbergh herd. Landscape metric values within Lindbergh hunting season core areas tended to be different than those for the entire home range, but were more distinctly so during the NEW study period (Table 8). The directions of those differences were the same as for the Chamberlain herd: Core areas had much higher values for MEAN PATCH SIZE, PATCH RICHNESS DENSITY, CONTAGION, and CONIFEROUS FOREST CORE AREA, and much lower values for PATCH DENSITY, EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX than the home range. PATCH DENSITY , MEAN PATCH SIZE, EDGE DENSITY, and CONTRAST-WEIGHTED EDGE DENSITY values for cores, however, were similar to those values for the home range during the OLD study period. Means for the selected landscape metrics are presented in Table 10.

Changes in core area metrics between old and new studies

Chamberlain herd. With one exception, values for landscape metrics within hunting season core areas did not change greatly between the two periods of study (Table 11). Most changed slightly, however, with increases in EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX, and decreases in INTERSPERSION AND JUXTAPOSITION INDEX, CONTAGION, and CONIFEROUS FOREST CORE AREA. INTERSPERSION AND JUXTAPOSITION INDEX was much lower within NEW core areas than within OLD cores. Means for the selected landscape metrics are presented in Table 9.

Lindbergh herd. Values for landscape metrics within Lindbergh hunting season core areas did not change greatly between the two periods of study either (Table 11). Changes were noted

however, with increases in values for MEAN PATCH SIZE, CONTAGION, and CONIFEROUS FOREST CORE AREA, and decreases in PATCH DENSITY, EDGE DENSITY, CONTRAST-WEIGHTED EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX, and INTERSPERSION AND JUXTAPOSITION INDEX within hunting season cores between the OLD and NEW studies. Means for the selected landscape metrics are presented in Table 10.

Changes in core area metrics, relative to changes in home range metrics

As previously noted, values for landscape metrics within hunting season core areas changed little between the two study periods for both elk herds. The changes that did occur, however, tended to parallel the changes within the home range for the Chamberlain herd and move in the opposite direction as the home range for the Lindbergh herd.

DISCUSSION

Fixed kernal 95% home ranges and 50% core areas were generated for any season with 35 or more elk locations. Many seasonal samples of elk locations were too small for home range analysis and meaningful designation of core areas and many home range calculations produced cores < 100 ha . For these reasons, rut locations were lumped together to form a cumulative core for the OLD and NEW time periods, rather than for each year; the same was done for hunting season locations. Generally, only one core resulted from these lumped time periods so statistical comparisons were not possible. Creating yearly cores was possible, however, for year-long and summer periods, which permitted statistical analyses of differences.

Within both the Chamberlain and Lindbergh home ranges the forested habitat became more fragmented: values for PATCH DENSITY, EDGE DENSITY, CONTRAST-WEIGHTED

EDGE DENSITY, MODIFIED SIMPSON'S DIVERSITY INDEX, INTERSPERSION AND JUXTAPOSITION INDEX increased, while values for MEAN PATCH SIZE, CONTAGION, and CONIFEROUS FOREST CORE AREA have decreased. Elk within these areas could react in three ways: (1) indifference to habitat changes would result in landscape metrics of core areas showing parallel changes to the rest of the home range; (2) selection for or (3) selection against these landscape metrics could be expressed if core areas contained higher or lower values than the entire home range.

Year-long

Generally, landscape metrics within year-long cores could not be differentiated from those for the entire herd home range, or from the OLD study period to the NEW. This could be interpreted in two ways: 1) Sample sizes were inadequate to detect any differences in landscape characteristics between core areas over time or between core areas and home ranges; or 2) averaging elk locations from seasons of differing needs resulted in the appearance of no habitat selection. The year-long analyses had the largest sample sizes of any comparison in the study and should have had better power to detect change than the summer analyses. More likely, constructing a core area from locations of different seasons, and differing seasonal needs, could have masked changes. Values for landscape metrics within year-long core areas can be found in Tables 8 and 9 for the Chamberlain and Lindbergh elk herds, respectively.

Summer

Fragmentation metrics within summer core areas showed that elk preferred areas that were more fragmented than their home ranges as a whole. Summer core areas contained more patches and more edge per unit area, higher contrast edge, and a greater diversity of vegetation,

and exhibiting smaller patches, low connectivity of similar vegetation types, and little closed canopy coniferous forest 100 m from edge. Differences between metrics of core areas and metrics of entire home ranges were more pronounced for the new study period than for the old, indicating that elk were selecting for fragmented places more than in the past. Summer core areas also tended to be more fragmented now than in the past, having core areas with higher density of vegetation patches, higher density of edge (Lindbergh), higher contrast edge (Lindbergh only), and high vegetative diversity (Lindbergh only), and smaller patches, low connectivity of similar vegetation types, and little closed canopy forest > 100 m from edge during the NEW study period than during the OLD.

The values for landscape metrics within core areas from the OLD to NEW study periods, showed the same trends as they did for the entire home range. In other words, as the forest environment became more fragmented, so did the areas of concentrated summer elk use. Mean patch sizes within core areas decreased from 28.3 to 19.5 ha within cores for the Chamberlain herd (Table 10), and from 48.1 to 28.3 ha for the Lindbergh herd (Table 11). Closed canopy coniferous forest core area decreased from 40.6 to 13.9 ha within cores for the Chamberlain herd and from 70.6 to 25.2 ha for the Lindbergh herd. It should be kept in mind that these patch sizes represent an average that included patches that were truncated by the core area boundary, the average of actual patches on the landscape would have been larger.

Rut

Landscape metrics within core areas were more variable for the rut than other periods. Although, the sample of cores was too small to analyze statistically, landscape metrics within rut cores during the OLD period displayed much variability. Because of this variability, little can be

concluded of differences between core area and home range metric values, or differences between core area values over time for this season. As with the year-long analyses, this could be as a result of too little data to detect change, or simply, much variability in the data.

The rut was the first season where large numbers of elk started using private land refuge, therefore, some core areas fell within private land refuge areas and were eliminated from analyses. Elk from the Lindbergh herd started using private agricultural land closed to public hunting during the OLD study period. Although this phenomenon will be discussed in more detail in another paper, it is the reason for a smaller sample of cores for analysis during the rut and hunting seasons, and illustrates the wide range of habitats that elk used at this time of year. Archery season for elk takes place during the rut, and although hunting pressure within the study area was relatively light, it may have created additional habitat needs for elk. Elk were commonly located in a wide range of habitats during the rut, including private agricultural areas, harvested forest lands, and undisturbed, high elevation, coniferous forest. This variability was reflected in the landscape metrics for rut core areas. Values for landscape metrics within rut core areas can be found in Tables 8 and 9 for the Chamberlain and Lindbergh elk herds, respectively.

Hunting Season

In contrast to summer, hunting season core areas showed less fragmentation than their home ranges as a whole. Hunting season cores contained larger patches, higher connectivity patch types, more closed canopy coniferous forest 100 m from edge, and lower density of patches, lower density of edges, and lower contrast edges than their entire home ranges. For the Chamberlain herd, OLD hunting season cores contained nearly no edge or edge contrast, and very little vegetative diversity. Edge, edge contrast, and vegetative diversity increased slightly

within NEW hunting season cores as they did within the entire home ranges. In other words, hunting season cores consisted of few, relatively large, forested patches. For Lindbergh elk, these metrics within core areas were similar to the values of the entire home range, yet declined for cores during the NEW study.

Core area landscape metrics for the Chamberlain herd paralleled those within the entire home ranges. For the Lindbergh herd, core area landscape metrics for the hunting season showed less fragmentation during the NEW study than during the OLD. Lindbergh hunting season core area values were similar to home range values during the OLD study, but tended to show less fragmentation during the NEW study. This indicates that Chamberlain elk selected areas of similar structure during the hunting season during the NEW study as they did during the OLD study, while Lindbergh elk, when they were not on private land, looked for less fragmented areas than they did during the OLD study. It must be kept in mind, however, that most Lindbergh elk were using private land refuge during hunting season during the NEW study, and that cores that fell within this private land were omitted from analysis.

Mean patch sizes for hunting season core areas were markedly larger than for summer cores, and increased from the OLD to NEW studies. Patches within Chamberlain hunting cores averaged 184 ha for the OLD study and decreased to 161 ha during the NEW study (Table 10) while for Lindbergh hunting cores they increased from 47.0 to 93.0 ha (Table 11). These larger patches were mostly closed canopy coniferous forest and comprised from 69 to 85% of hunting season cores for both herds, during both study periods. Summer cores contained much less closed canopy coniferous forest core ranging from 13 to 41% for the Chamberlain herd and 25 to 70 % for the Lindbergh herd.

In summer, elk selected areas that were more fragmented than their home ranges as a whole. Summer core contained many patches, much edge, high vegetative diversity, and small mean patch sizes, low connectivity, and little closed canopy coniferous forest core. This was more evident within the home range as a whole and during the new study period. Mean patch sizes within summer cores were less than 30 ha for both elk herds, significantly less than the means for the entire home ranges. Elk made heavy use of harvested lands for foraging and raising calves and used small patches of forest for cover. Disturbances at this time of year were few, consisting of localized logging and administrative activity.

During hunting season however, elk avoided areas showing high fragmentation indices and selected areas that were relatively un-fragmented. Hunting season core areas focused on un-fragmented areas characterized by low patch densities, low edge densities, low diversity, large mean patch sizes, high connectivity, and a large amount of coniferous forest core area. Mean patch sizes within hunting season cores were over 150 ha for the Chamberlain herd and over 90 ha for the Lindbergh herd during the new study. Significantly greater than the mean patch size for the entire home ranges. Closed canopy coniferous forest core area comprised 69 to 85% of the hunting season cores. Elk use of adjacent, protected private lands during the hunting season, has increased throughout the entire period of study. Reduction of closed canopy forest cover is likely a factor contributing to this trend.

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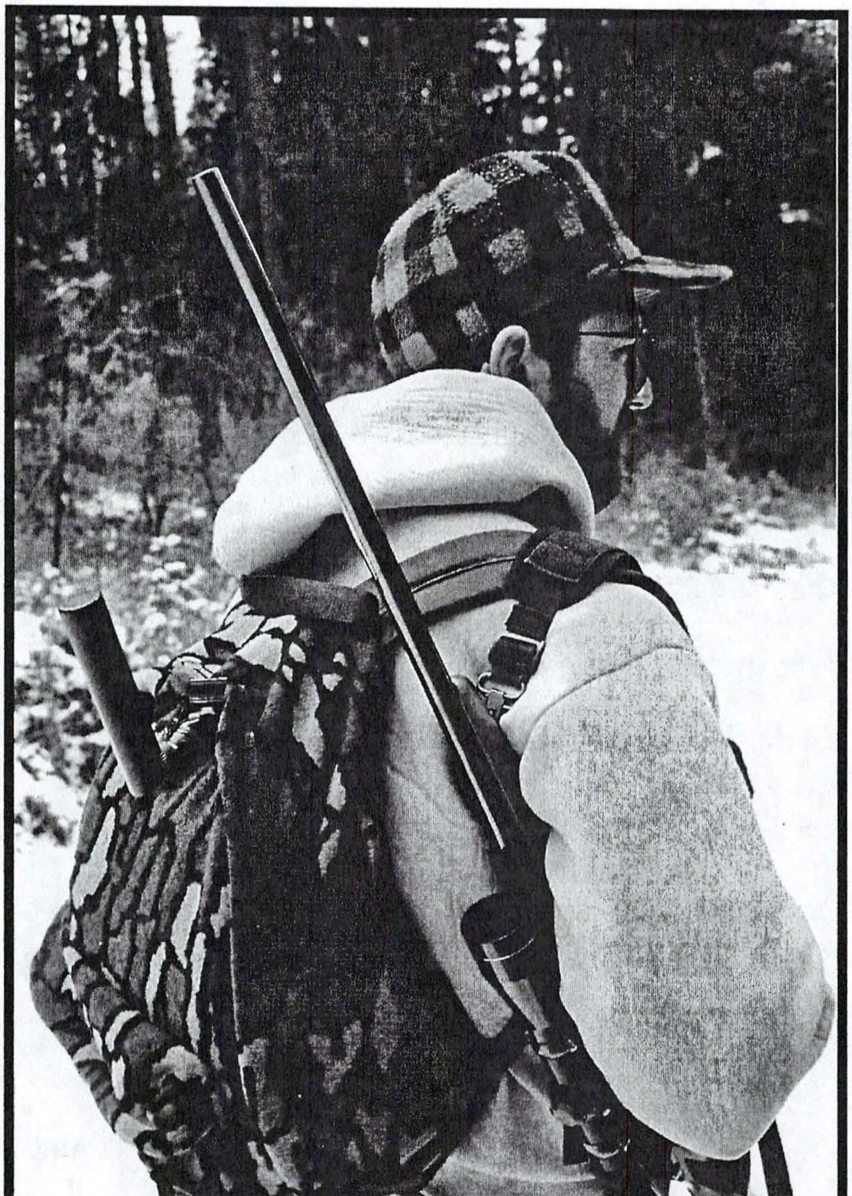
Chapter 5

TRACKING ELK HUNTERS WITH THE GLOBAL POSITIONING SYSTEM



TRACKING ELK HUNTERS WITH THE GLOBAL POSITIONING SYSTEM

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***Abstract*:** We examined elk-hunter behavior and movement patterns within an area that has no motorized access. We used Global Positioning System (GPS) units to record hunter locations at 15 second intervals during 99 hunting expeditions in 1993, 1994, and 1995. Subsequent analysis within a Geographic Information System (GIS) enabled us to determine that hunters averaged 4.7 hours per hunt while moving at a speed of 40 m per minute for a distance of 10.7 km. Sixty percent of all hunting took place on slopes less steep than the study area average, and westerly aspects were favored. Only one-half of all hunters traveled more than 2.5 km from their starting point, and only 12.5 percent traveled more than 4.5 km. The average distance from the nearest road while hunting was only 267 m, and hunters on foot spent 26 percent of their hunting time on roads. Hunters who spent the most time on roads also recorded the greatest distances from their starting point. Forests were selected over sagebrush by elk hunters, but they avoided lodgepole pine and chose more open forest types with mature trees.

***Key Words*:** behavior, elk, Cervus elaphus, GPS, hunter, Montana, vulnerability

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In recent years, research on management and protection of North American elk has expanded beyond purely biological considerations. Resource managers have demonstrated that

they can produce elk in a variety of habitats. We are now entering an era in which we will have to consider some of the ethical and moral reasons for doing so. If elk hunting is to continue as legitimate recreation, consideration must be given to controlling harassment of wildlife and the behavior of the participants.

In 1991, the Elk Vulnerability Symposium (Christensen and others 1991) produced a state-of-knowledge compendium, including an evaluation of our understanding of elk mortality during the hunting season. Among the defining parameters of elk vulnerability to hunting, various authors identified road densities, hunter numbers, topography, cover quality, hunting regulations, and changing technology.

All of these parameters affect elk populations through direct or indirect modification of hunter behavior. However, the existing information describing hunter behavior is almost entirely confined to interview results. Smith and Yuan (1991) cite seven studies in which hunter behavior was determined by questionaire. They cite no studies in which actual hunter behavior in the field was recorded and reported. Bryant and others (1991) tracked hunters with LORAN-C, but they reported only the interactions with elk. The most nearly comparable study of hunters, reported by Thomas and others (1976), asked hunters to draw their daily travel routes on maps. We believe GPS units carried by hunters provide better information because data are unaffected by hunter memory or the ability to interpret maps. We examined hunter behavior and movement patterns in an area with no motorized access.

STUDY AREA

This research was conducted during the 1993, 1994, and 1995 elk hunting seasons in the Garnet Mountains, south of the Blackfoot River in western Montana (Fig. 1). The primary study area included about 1000 square kilometers centered around Bata Mountain and the Blackfoot Block Management Area. There was a mixture of Bureau of Land Management, State of Montana, and private (Plum Creek) timberland as well as old mining claims, commuter inholdings, and several cattle ranches. Some of the timberlands have been heavily harvested, but there were roadless areas remaining within a landscape that rises from the Blackfoot River floodplain at about 1100 m to the mountain peaks along the Garnet Divide at 1800 m. The average slope on the study area, measured at 30 m intervals on a digital elevation model, was 22 percent. About one-third of the area had slopes greater than 30 percent, but less than 1 percent of the slopes were over 70 percent. The Blackfoot Management Area is a road-closure management unit, open to the public, in which primary access points, trailheads, are located at gates, and most of the hunters can be readily counted and contacted. Elk hunting in this area begins early in September with the archery season; the rifle season starts the third week in October and continues for 35 days. A limited number of cow permits are issued in a random drawing, but antlered bulls are legal to anyone holding a Montana elk license. Thus, the primary hunting pressure falls on the bull elk segment of the population.

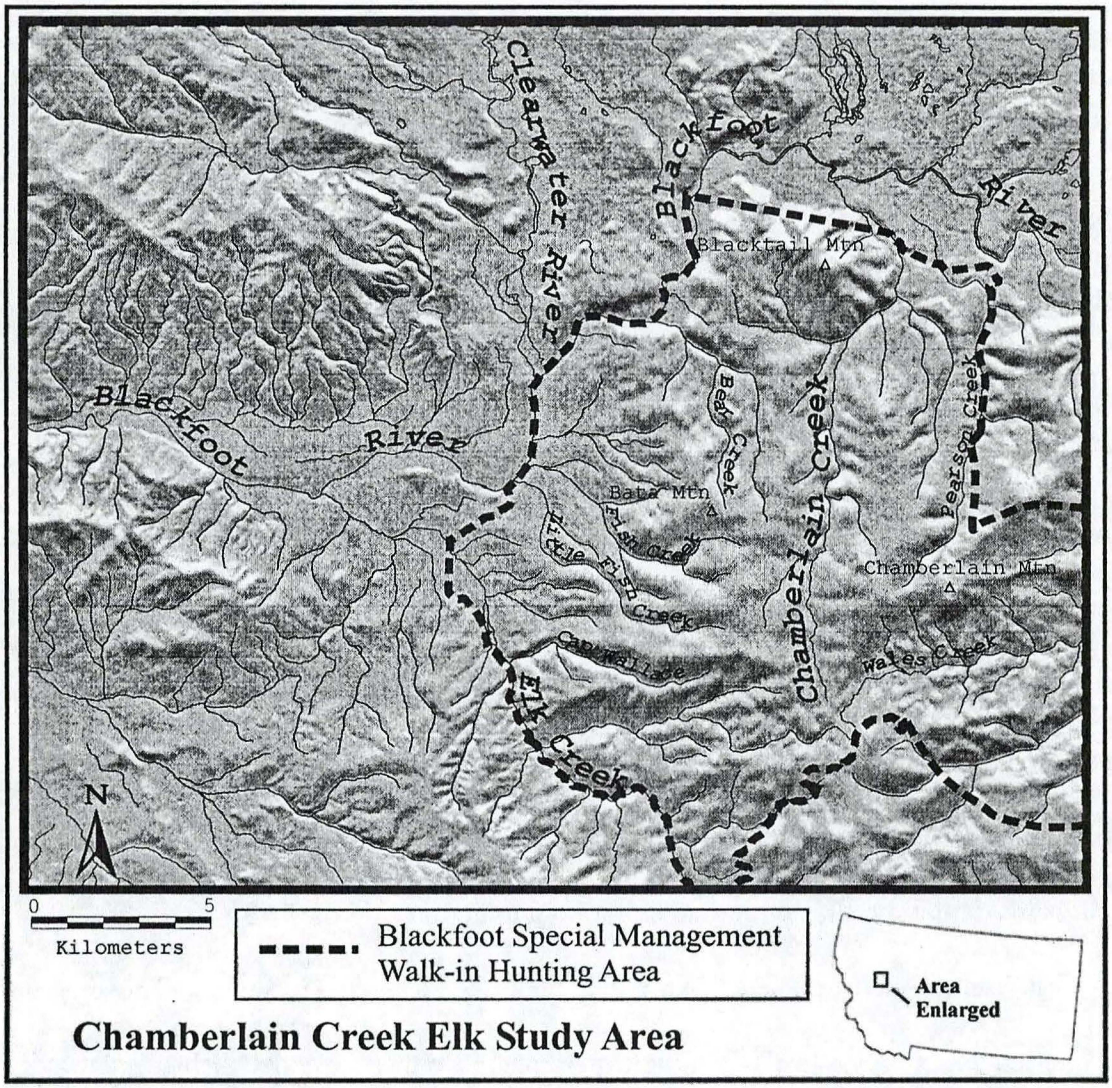

Figure 1. Study area and approximate boundary of the Blackfoot Special Management Walk-in Hunting Area.

STUDY METHODS

During three fall hunting seasons, Global Positioning System (GPS) recorders (GARMIN 100 SRVY) were carried by elk hunters while hunting. These battery operated units can continuously record geographic positions at intervals of 2 or more seconds with about 6 hours battery life and data storage capacity over 4,000 locations. We selected 15 seconds as an appropriate time period for maintaining satellite contact while providing adequate data replication to detect movement distances as little as 15 m. The manufacturer's specifications indicate 5 to 15 m accuracy for autonomous averaging with Selective Availability turned off and 40 m if Selective Availability is on. Since neither estimate would lead to greater loss of accuracy than already inherent in the 30 m pixels of our digital elevation model and Landsat coverages, we did not attempt differential correction. Our primary confirmation of accuracy was empirical comparison of hunter routes with road and topographic maps in the GIS.

Elk hunters were contacted in the field and asked to carry GPS units. Those who agreed were queried about previous elk-hunting experience. We then provided written instructions for starting the GPS unit, obtaining satellite coverage, and initiating the tracking mode. When possible, we arranged to be present to start the units. The GPS units were normally carried inside a backpack with the antenna protruding on a short cable.

At the end of each hunting day, data were downloaded from the GPS units to a computer and examined in a GPS graphics program. To reduce receiver-induced, atmospheric, and signal multipath location variance, all data were smoothed to a five-point running average. Global Positioning System locations were projected to UTM (Universal Transverse Mercator)

coordinates to create Arc/Info point coverages of hunter routes. Distances between points were used to determine average speed of movement and total distance moved. Point coverages in Arc/Info were overlaid on a vector map to determine distances to the nearest road. When the distance was less than 50 m, we assumed the hunter was on the road. We determined slopes and elevations for each point using digital elevation model point coverages in Arc/Info.

Vegetation

After analysis and reclassification of a Landsat Thematic Mapper coverage, a map was projected to an Arc/Info vector coverage of vegetation polygons with 23 verified classes. Point coverages of hunter routes were overlaid on the polygon coverage to determine the time spent by hunters in each vegetation class. We also created 80 random transects of points using the average speed and distance recorded on hunter routes. These transects provided an unbiased estimate of the time potentially available to hunters in each vegetation class.

Data Summary and Analysis

The information compiled for each GPS record provided data for one "hunter-day." In some records there were gaps because of poor satellite coverage, and in a few cases, battery life was exceeded by the length of the hunt. We were able to reconstruct short sections of missing data, but even when this was not possible, every record provided some information concerning the time spent hunting, distance traveled, speed of travel, maximum distance from starting point, and elevational change as well as summaries of slopes and aspects hunted, use of both closed and

open roads, and use of available vegetation types for hunting. We calculated the average distance from roads, time spent on roads, and maximum distance from any road. In developing a comprehensive examination of the way roads are used, we separated hunts into four groups using maximum distance from starting point. Among groups, we compared the percentage of time spent on roads, and within groups we examined the constancy of road usage at increasing distances from the starting point.

Because the primary purpose of this study was to provide a descriptive baseline of hunter behavior, statistical tests are not particularly informative. Where possible, however, we compared hunters on foot with those on horseback and evaluated differences among three hunter-experience groups. In most comparisons, we used a t-test of the difference between group means. Vegetation selections were examined in an analysis of variance comparing average time spent by hunters against average time on random transects in each vegetation class.

RESULTS AND DISCUSSION

During the 1993, 1994, and 1995 hunting seasons, we obtained GPS records for 99 elk hunts involving 50 different hunters. Fifteen individuals carried GPS units for more than one hunt, five recorded more than two hunts, and seven participated in the study for at least 2 of the 3 years. The average recording contained 898 locations, and although about one-fifth of all recordings were incomplete, every recording containing more than 200 locations provided some useful information.

We obtained records for five archery hunts and 94 rifle hunts. Most elk hunting is done

on foot, but we recorded 15 hunts using horses, and three were conducted entirely from a moving vehicle. On four hunts, a bicycle was used to get from the trailhead to a hunting site, and on two hunts, a snowmobile was used to reach the hunting site. Nineteen of our hunters started from overnight camps while 75 initiated hunts from trailheads.

Hunters in our sample averaged 41 years of age (range 14 to 71), and 96 percent were men. This compares to averages of 37 years and 95 percent men reported for Montana elk hunters by Allen (1988). Hunting experience in our sample included 10 hunters who had never killed an elk, 30 who had killed at least one elk, and 16 hunters who had killed more than five elk. The least experienced hunters averaged 36 years of age, while the more experienced averaged 42 years, and the most experienced averaged 44 years. Three hunters killed an elk while carrying GPS units.

In the following data summaries, we provide means and indicate sample sizes, but we mention significant differences only when the statistical probability was 0.05 or less. None of the averages we present are based on the full 99 records. Our largest samples include the 70 to 80 hunts in which walking was the primary mode of travel. The behavior and actions of elk hunters seem consistent in these data, but we recognize some apparent inconsistencies in smaller samples.

Time Spent Hunting

For the 77 hunts on which we have complete information, the average time spent per hunt was 4.7 hours. Walking hunters averaged less time per hunt (4.5 hr, $n = 65$) than those using

horses (5.5 hr, n = 12), but the most experienced walkers spent significantly more time (5.6 hr, n = 11) hunting than the least experienced (4.4 hr, n = 8). Montana hunters told Allen (1988) that they averaged 8 hours hunting each day, but that estimate was probably not limited to actual "weapon-in-hand" minutes.

Yuan, Smith, and Zager (1991) reported that hunters interviewed in Idaho spent 10 percent of hunting time sitting or standing still. In our data, we classified moving at a pace slower than 10 m per minute as equivalent to sitting or standing. Hunters in this study invested 9 percent of their time in this technique, and nearly one-fourth of them spent over 10 percent. Archery hunters (n = 5) were not significantly different in this respect, or in any other characteristic of hunters on foot, and for most of our analysis they are included in the averages without differentiation.

Distance Traveled

Distances traveled in 78 complete hunting expeditions averaged 10.7 km, the greatest recorded distance for a single hunt was a horseback trip of 31.7 km. Hunting with a horse significantly increased the average travel distance (16.8 km, n = 11) over the average distance by hunters on foot (9.5 km, n = 63). Bicycle hunters also covered great distances (average 18.0 km), but our sample was too small to be considered characteristic. Among hunters on foot, the average distances traveled are comparable to the median distance of 6 miles (9.7 km) reported by Allen (1988) for Montana hunters. In our sample, hunters with the most experience walked significantly greater distances (12.6 km, n = 10) than those with moderate experience (8.7 km, n

= 45); the least experienced hunters averaged an intermediate distance (10.0 km, $n = 8$).

The total distance traveled provides only a partial description of any elk hunt. In terms of elk vulnerability, it may be more important to determine the maximum distance away from the trailhead or starting point. For the 93 hunts in which maximum distance from starting point could be determined, the average was 2.6 km. Less than one-half of the hunters went farther than that, and only 12.5 percent reached a point further than 4.5 km from their starting points. In this maximum-distance group, there were five walkers, five on horseback, and one using a bicycle.

Speed of Travel

Hunters in our sample used several different methods to get from one place to another. We report the average speed of each method for comparison purposes. We only considered individuals to be hunting when walking or on horseback. In getting to or from a hunting site, however, bicycles rolled along at 109 m per minute, snowmobiles at 224 m per minute, and pickup trucks at 208 m per minute (a little less than 8 mph). The average speed of movement for sportsmen actually hunting was 40 m per minute ($n = 93$). Hunters on foot averaged 37 m per minute ($n = 78$), which was significantly slower than the horseback pace of 51 m per minute ($n = 15$).

Elevational Change

In addition to horizontal distances, we examined the vertical elevations covered by 93 elk hunters. The difference between the highest and lowest points reached on various hunts ranged

from 33 to 807 m. The average was 306 m, and there were no significant differences associated with walking, with horses, or with bicycles.

Slope Selection

The average slope on hunter routes was 21 percent. Overall summaries show that hunters spent 60 percent of their time hunting areas less steep than the average for the study area (22 percent). The only slope-associated change in behavior was that walking speed on slopes under 10 percent was nearly 2 m per minute faster than on slopes over 30 percent (37.6 versus 35.7 m per minute). This difference was signficant because we had over 10,000 observations for each mean, but we suspect that the statistic, in this case, is not particularly important.

Aspect Selection

Our evaluation of hunter response to aspect compares the amount of time spent by elk hunters on each aspect with the area of that aspect available. Availability is based on the summary of nearly 500,000 30 m pixels in the digital elevation model coverage. Data were summarized by percentage distribution (Table 1) within an octant (45 degree arc). While there is an indication in these data that hunters selected westerly aspects, we hesitate to suggest any conclusion about hunter behavior until this study is replicated in some other geographic area.

Table 1--Percentage distribution by octant of aspects available to hunters, and aspects selected by hunters in 96 elk hunts.

	Octant							
Category	**NNE**	**ENE**	**ESE**	**SSE**	**SSW**	**WSW**	**WNW**	**NNW**
Used by hunters	15	13	10	7	10	15	16	15
Available	16	14	11	10	9	12	14	13

Use of roads

In the average 4.5 hours (271 minutes) spent hunting by elk hunters on foot, 70 minutes were spent walking on roads. Hunters with the least experience spent 40 percent of their hunting time on roads; those with the most experience spent 27 percent. The majority of roads in the Blackfoot Management Area area were closed to motor vehicles, but the summary statistics indicate that elk hunters on foot spent an average 13 to 14 minutes per hunt walking on roads actually accessible to motor vehicles. Hunters on horseback spent only 47 percent of their time on roads. However, this average was likely biased by a single individual riding the off-road ridgelines.

Because roads are such a significant part of the environment for elk in this area, we attempted several different approaches in examining the influence of roads on hunter behavior. Our conclusions are clearly subjective because the tests were intended to identify the role of roads in influencing hunter behavior and, ultimately, elk vulnerability.

The average walking speed for hunters on roads, 42 m per minute ($n = 75$), was significantly faster than the off-road walking speed of 36 m per minute ($n = 78$). Walking speeds on roads increased to 44 m per minute when adjacent slopes were over 30 percent, but walking speeds off roads declined to 33 m per minute on slopes over 30 percent. None of these movement speeds approach a normal walking pace, and observed differences might simply be attributed to the relative ease of walking on a nearly flat surface. However, if reduced movement speed is interpreted as representing greater concentration on hunting, these data imply that roads are more important for getting from one place to another than for actual hunting.

Possibly the most informative observations in regard to road use can be developed by examining the percentage of time spent on roads by hunters reaching different maximum distances from their starting point. During hunts in which the maximum distance from start was greater than 2.5 km ($n = 44$), hunters spent 38 percent of their time on roads. This was significantly more time than the 20 percent on roads by hunters ($n = 49$) who did not reach 2.5 km. In a further examination of these data, we split the distance categories at 1.5 and 3.5 km and calculated the percentage of time spent on roads in 500 m increments from the starting points (Table 2).

In confirmation of expectations, hunters going to greater maximum distances spent a higher proportion of time on roads than hunters who invested their hunting effort near the trailhead. It was, nevertheless, unexpected that these hunters did not eventually leave the roads. On the contrary, the evidence in Table 2 shows that beyond 1500 m, one-third to one-half of all hunting takes place on roads if roads are present.

Distance from Roads

Any apparent preference for hunting on or near roads may simply indicate the heavily roaded character of the study area. After eliminating those observations in which a hunter was on or within 50 m of a road, the average distance to any road for all hunters while hunting was only 267 m ($n = 96$). Only three hunters managed to get farther than 1.0 km from a road, and the average maximum distance from a road for all hunts was only 565 m. Hunters on foot maximized the distance from roads better than hunters with horses (591 m versus 420 m), and the

Table 2-- Percentage of time spent on roads by elk hunters in 500 m distance bands within 4 categories of maximum distance from trailhead.

			Maximum distance from starting point									
Distance category[a]	***n***	**Mean**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5000+**
							percent					
<1.5 km	27	16	19	8								
1.5-2.5	22	24	26	26	21	38						
2.5-3.5	23	34	41	34	46	31	31	32				
>3.5 km	21	42	55	44	38	29	35	46	46	54	47	43

[a] Mann-Whitney U for adjacent distance categories confirms significantly more time spent on roads with each increase in distance from trailhead (P:0.07, 0.06, 0.05).

most experienced hunters traveled further from roads than hunters with the least experience (702 m versus 444 m), but none of these differences were significant.

Vegetation Selections

A summary of polygon areas, taken from the Arc/Info coverage, shows the study area is 78 percent forested and 22 percent nonforested (Table 3). In estimating the amount of time spent by hunters in each vegetation class, we eliminated all sample points in which a vehicle, snowmobile, or bicycle was used. Our summary included only vegetation classes in which at least 1 percent of the hunting effort was recorded, plus two classes that were specifically avoided by hunters.

Some hunting time was recorded in 20 of the 23 vegetation classes available to hunters, but over 98 percent of all hunting occurred in only nine classes, and over 80 percent occurred in the six forest types containing mature trees. Our random sample transects indicated lodgepole pine forests should have been hunted for 59 minutes in an average hunt, but the elk hunters spent significantly less time -- only 31 minutes (n = 1,174). The Open Douglas-fir, however, was relatively attractive to hunters and received 40 minutes of use as compared to the 23 minutes predicted on random transects (n = 1,174). The attraction of mature trees in open stands is further indicated by selection of both Ponderosa pine and Western Larch vegetation classes, even though these forest types are a limited component of the vegetation. Sagebrush and Rangelands were both avoided by significant margins, but this is hardly a surprise because neither offers any kind of security cover for elk.

Table 3-- Vegetation classes used by elk hunters, predicted[a] and actual time spent hunting in each class, percentage area[b], and physical characteristics[c] of each class.

	Minutes hunting				
Vegetation class	Predicted	Actual	Percent of area	Basal area	Canopy cover
Douglas-fir	60	61	23	25.0	64
Lodgepole pine	59	31*[d]	21	37.0	62
Mixed conifers	36	45	18	17.0	57
Open Douglas-fir	23	40*	11	8.6	28
Foothills parkland	12	14	7	4.1	10
Clearcuts	11	15	5	3.2	9
Regenerated clearcuts	5	4	2	2.3	40
Sagebrush	4	1*	4	0.1	5
Rangeland	3	1*	2	<1.8	<15
Ponderosa pine	3	4	2	18.9	31
Western larch	2	7*	1	7.9	42

[a] Predicted times from random transects of points generated at the average movement speed of elk hunters on GPS transects.
[b] Area percentages taken from Arc/Info coverage.
[c] BA is m^2/km^2 and canopy is percentage crown closure.
[d] Asterisk indicates a significant difference ($\underline{P} < 0.05$)

MANAGEMENT IMPLICATIONS

Most of the information summarized in this study will allow us to assign numbers to information already recognized but not numerically defined. On average, a day spent hunting elk involves walking slowly for 4 to 6 hours and traveling 10 to 12 km. Elk hunters are selective in choosing forested areas with mature trees, but they seem to prefer hunting in areas where the hiding cover is inadequate and visibility is high. This selection is extremely important in evaluating elk vulnerability. Weber (1996), in a study of landscape effects on elk vulnerability, found that while only 4 percent of live elk locations during the hunting season were in Open Douglas-fir, 17 percent of the kills occurred there.

Less than half of all hunters will travel farther than 2.6 km from their starting point, and only 12.5 percent will travel as far as 4.5 km. Hunters who go the greatest distance from trailheads spend a great deal of time on closed roads. Where such roads are present, horses, bicycles, and walking are all highly effective transportation modes. Our most important observation is that closed roads have a significant impact on hunter behavior. We hypothesize that closed roads facilitate access to areas most distant from open roads and trailheads. This information and the associated time and distance data provide a solid foundation on which a hunter density and elk vulnerability model can be developed.

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Chapter 6

REDUCING ELK VULNERABILITY WITH ROAD CLOSURES AND LANDSCAPE MANAGEMENT: A MODEL

REDUCING ELK VULNERABILITY WITH ROAD CLOSURES AND LANDSCAPE MANAGEMENT: A MODEL

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Abstract: We examined hunter distribution within a 243 km^2 road-closure unit in western Montana using predictions based on GPS records of hunter movement. The average number of hunters recorded at trailheads and camps on opening day of elk hunting season (1993-1995) was 165.6 and the calculated hunter density was 0.68 hunters/km^2. However, when hunter distribution was examined, we found hunter density exceeded 5.0 hunters/km^2 on 47.6 km^2, while 59.3 km^2 had less than 0.5 hunters/km^2. Nearly 30 % of the area sustained hunting pressure less than our estimate of 0.68. These data suggest that hunter densities for large areas are often overestimates while elk escapement depends on site specific hunter densities at much lower levels. Even though the relationships between hunter density and elk escapement have not been well described, we propose that at least 30 % of a walk-in area should support hunting pressures below 0.5 hunters/km^2 and describe a GIS model which will facilitate such estimates.

Key words: elk vulnerability, road closures, hunter density

During the past 15 years, the Rocky Mountain elk has achieved status as the premier big game species in North America. North American elk populations are higher than at any time in the past century, and elk license sales have reached record levels throughout the Western United States. Mature bulls represent a major attraction in elk hunting, and it is the bull segment of the population that absorbs most of the pressure during the hunting season. However, unlimited bull hunting has invariably produced decreases in bull:cow ratios and a reduction in the average age of breeding bulls (Carpenter 1991, Hamlin and Ross 1991, Vales et al. 1991). In some herds, the breeding bulls are almost all immature animals (Leckenby et al. 1991).

For hunters, it is clear that no trophy bulls will be available if all bulls are killed before they reach maturity. And, for the non-hunter, it is equally clear that the mature bull as a visual resource will cease to exist. The full significance of bull elk vulnerability, however, has only been recognized during the last decade as managers have begun to examine the biological consequences of low bull numbers, including a relaxation of natural selection (Geist 1991), reduced pregnancy rates (Squibb et al. 1991), and an increased probability of late calving (Noyes et al. 1996). These are especially difficult problems where the management objective is to design hunting situations that will produce adequate bull escapement without minimizing the number of participants.

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PAST RESEARCH

The Elk Vulnerability Symposium (Christensen et al. 1991) consisted of over 60 papers in 15 sessions providing a state-of-knowledge review including "...information of unusual scope and depth on a single subject." (Thomas 1991). And, while the overall scope of vulnerability was.... The variables of elk vulnerability over which resource managers have some control are limited, but the most important are usually considered to be vegetation management, road management, and limitations on hunters. Topography has also been identified as a contributing determinant of elk vulnerability (Irwin and Peek 1983, Marcum et al. 1984, Edge and Marcum 1991, Unsworth et al. 1993, Vales 1996), but one that offers little opportunity for modification by managers. In predicting bull elk mortality, both Unsworth et al. (1993) and Vales (1996) have shown that the probability of mortality decreases as topographic complexity rises.

Vegetation Management

Among vegetation parameters that affect vulnerability, various authors have identified different combinations of cover quality, cover quantity and habitat fragmentation. An array of hunting-season studies have demonstrated elk movement to better hiding cover or more dense timber patches (Irwin and Peek 1983, Canfield 1988, Hurley and Sargeant 1991, Weber 1996). Irwin and Peek (1979:203) reported that smaller timber stands, near 30 ha in size, "...provided security for... elk for at least several days... when roads were closed."

However, larger patches are certainly better. Lyon and Canfield (1991) found that elk consistently selected a conformation of habitats providing access to larger, continuous forest communities during the hunting season, and Hillis et al. (1991) proposed a minimum cover patch size of 100 ha (250 acres) to provide security.

The effectiveness of such a patch is, however, contingent on the absence of roads within a half mile. In most forest habitats strong correlations between cover and road density tend to obscure any independent influences. Security cover ranked less important than road density and hunter numbers in Vales (1996) elk vulnerability model (ELKVULN). Where massive cover reduction at the landscape level is combined with high road densities, bull elk vulnerability becomes so high that a significant loss of hunting opportunity is inevitable (Leckenby et al. 1991).

Road Management

Road-related variables have been implicated as increasing elk vulnerability in virtually every study in which the influence of roads has been examined. Bull elk vulnerability is highest in areas with open roads, reduced in areas with closed roads, and lowest in roadless areas (Leptich and Zager 1991, Unsworth and Kuck 1991, Unsworth et al. 1993). Hunted elk avoid open roads and select habitats as far as possible from the nearest open road (Marcum 1975, Irwin and Peek 1979, Lyon and Canfield 1991, Weber 1996), and those elk that remain in areas with open roads are three times more likely to be killed (Hurley and Sargeant 1991).

Limitations on Hunters

The primary approaches to direct control of hunters have involved controlling the length and timing of the hunting season, defining the age and sex of legal animals or directly limiting hunter numbers. Research directed to limiting the structure of the harvest through hunting regulations has a long and complex history. Antler-point restrictions (Carpenter 1991), calf-only (Demarchi and Wolterson 1991), spike-only (Vore and DeSimone 1991) and branch-antlered (Hamlin and Ross 1991) hunting seasons have all been tested for the effect on bull elk survival. In general, however, such regulations have only served to shift the harvest to a different age group. The real problem, as Carpenter (1991:16) has pointed out "...is one of reducing hunting pressure,...", which is best accomplished by "Shorter seasons, split seasons, and limited entry options..." (Leckenby et al. 1991:92). Vales et al. (1991:181) concluded that, "Vigorous management of hunter numbers and/or hunter effectiveness ... is required to enhance sex ratios in most circumstances..."

Reduced Hunting Pressure

One potential method of reducing hunting pressure without unduly restricting opportunity is by limiting vehicle access within an administratively designated 'walk-in' area. If access is limited to non-motorized methods, the interior of such an area can play an important role in providing escapement and reducing elk vulnerability. Past research has shown the effect of road closures varies in reducing vulnerability, but we do not have enough information to pinpoint the exact causes. Basile and Lonner (1979) reported one

road-closure that substantially prolonged the harvest without increasing the total kill and a second closure in which a slight increase in harvest was recorded. They attributed the differences to the amount of security cover available, but either result could have been interpreted as resulting from modifications in hunter density and distribution.

We are not aware of any research that even suggests a threshhold for hunter density, and in any case it is extremely difficult to compare hunter densities expressed by different authors on unstandardized scales. Vales (1996) has shown that a ratio of hunters to vulnerable elk that exceeds 1:1 will likely produce 20-45 % mortality of elk. His hunter numbers are based on permit totals independent of geographic area and cannot be expressed as density. Squibb et al. (1986) concluded that 1.2-1.4 hunters/km^2 were sufficient to disrupt breeding behavior in Utah. We have assumed Squibb used permit totals because an earlier report from the same study area (Kimball and Wolfe 1979) makes it clear that license sales were used to describe hunting pressure. Morgantini and Hudson (1979) also used permit numbers to estimate hunter densities, but in their study 50 licenses were issued for weekend hunts on a 35 km^2 study area. Thus, 1.4 hunters/km^2 represents a daily density for at least the first day of these hunts. The authors describe this as "heavy hunting pressure" under which 56 % of the hunters were successful.

The highest numbers we found for hunter density came from the Unsworth et al. (1993) study of elk mortality in north Idaho where they counted 5.9 to 6.9 hunter days/km^2 over a 54-day season. However, Yuan et al. (1991) found that the average hunter in north Idaho spent 5.5 to 6.0 days afield. Thus, we estimate the resulting bull mortality of 40 %

followed an opening day hunter density near 1.0-1.3 hunters/km^2.

Possibly the most specific and useful data have been reported from Starkey Experimental Forest and Range by Bryant et al. (1991) as case studies in which both hunter/elk ratios and hunter densities were known on a daily basis. Two of these hunts were confined to an area of 14.5 km^2 with relatively small numbers of hunters and elk. An August hunt for 10 branch-antlered bulls began with 2.3 hunters/elk and a hunter density of 1.6 hunters/km^2. Over a period of 9 days, 50 % of the vulnerable bulls were killed, the hunter/elk ratio declined to 1:1, and hunter density dropped to 0.3 hunters/km^2. In December, in the same area, a 7-day hunt of antlerless elk started with 5.4 elk/hunter, a hunter density of 0.83 hunters/km^2, and fresh snow on the ground. During one week of hunting, 83 % of the hunters successfullly harvested an elk. The third hunt described was an August hunt for spike bulls in a 78 km^2 area. In this hunt, the initial hunter density was 1.8 hunters/km^2, and the hunter/elk ratio started near 2:1 and declined to 1:1. Hunter success was 32 % and bull escapement was 29 %.

None of this information provides a clear picture of hunter density influences on elk vulnerability. It does appear that hunter densities higher than 1.0 hunter/km^2, especially if sustained for more than a few days, will result in either exceptional hunter success rates or survival by less than half the available elk. If such a heavy harvest is not the management objective, the manager needs a means of reducing hunter densities to achieve a more appropriate result. In this paper, we describe a method for estimating the probable hunter density within a hunting season 'walk-in' area and, where hunter numbers can be estimated,

a means of determining the size of an area that must be closed to motorized access if bull elk escapement is to be increased.

STUDY AREA

Our primary study area was located in the Garnet Mountain Range, south of the Blackfoot River in western Montana (Fig. 1). It includes about 1000 square kilometers centered around the 243 km^2 Blackfoot Block Management Area (BMA). Within this area, all the roads are closed to motor vehicles from September 1 to the end of the hunting season, and hunter access is restricted to foot travel, horses, or bicycles. The average density of roads in the closure area is 1.8 km/km^2, ranging from 0.0 to 3.7 km/km^2 in different drainages. In this part of the Garnet range, some of the forests have been heavily harvested, but there are roadless areas as well. Overall, the study area is considered 78 % forested and 22 % non-forested. Land ownership is a mixture of private cattle ranches, public and private timberland as well as old mining claims and commuter inholdings. Slopes average 22 % within a landscape that rises from the Blackfoot River floodplain at about 1100 m to the mountain peaks over 2000 m along the Garnet Divide.

METHODS

Hunter density is usually expressed as numbers of hunters per km^2, but the data to support a clear definition of what this means are only rarely available. Even when data are available, the temporal distribution of density can be selectively ignored or presented in ways that make comparison among studies nearly meaningless. Bryant et al. (1991) and

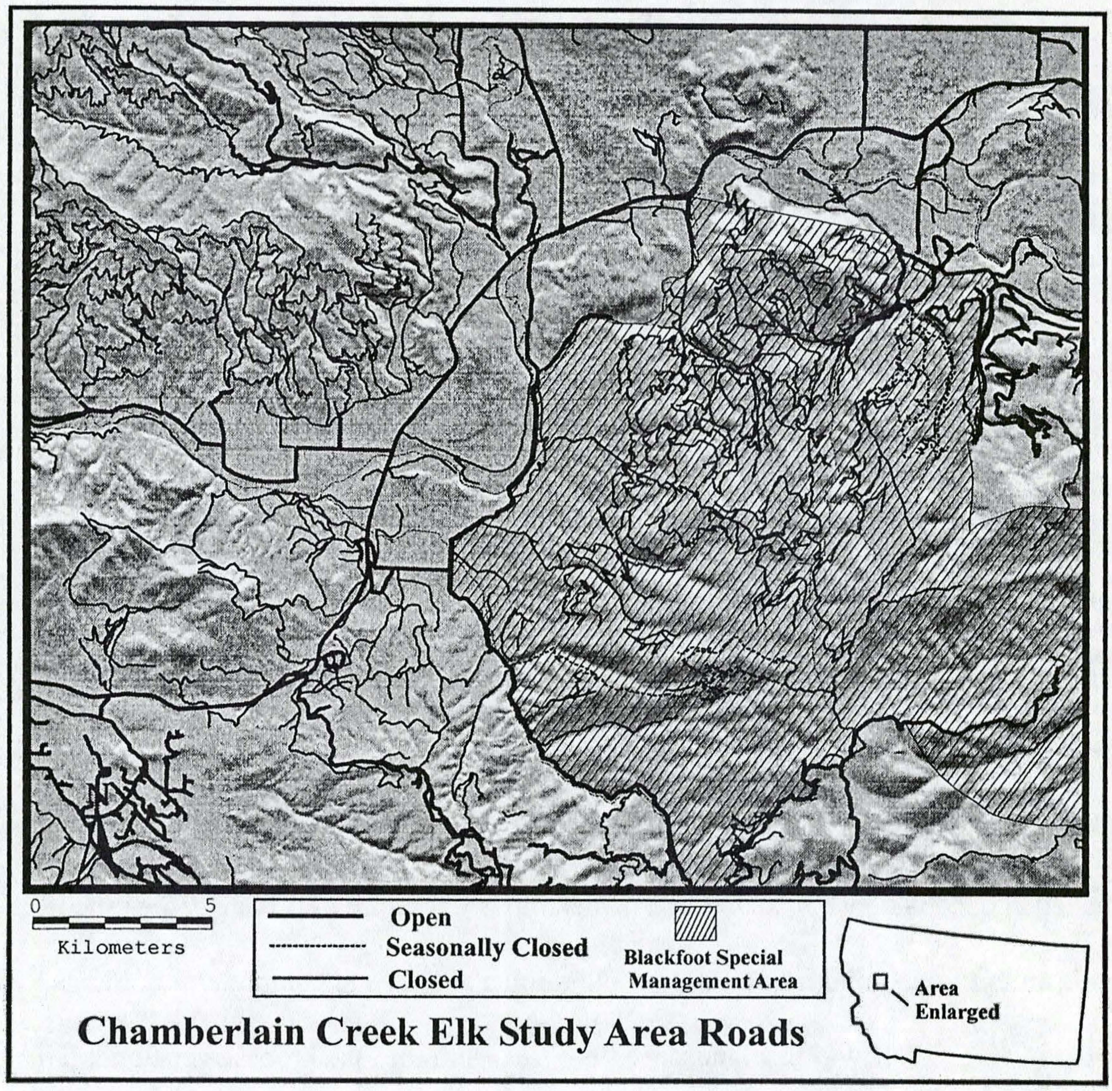

Figure 1. Study area showing roads and approximate boundary of the Blackfoot Special Management Walk-in Hunting Area.

Noyes et al. (1996) list the number of hunters on each day, while Unsworth et al. (1993) summed hunter days over a 54-day hunting season, and Squibb et al. (1986) and Vales (Vales et al. 1991, Vales 1996) have simply used the numbers of hunting permits issued. These differences in data presentation will produce orders of magnitude differences in descriptions of otherwise identical situations. For that reason, we arbitrarily define hunter density in this study as the number of hunters per unit area on a single day.

Even when appropriate data are available, predicting hunter distribution and site specific density is difficult because our understanding of hunter behavior in the wildland environment is normally based on assumptions that have not been confirmed or on interviews (Thomas et al. 1976, Smith and Yuan 1991) which cannot be verified in the field. In this study, hunter behavior was determined through examination of GPS records obtained during the hunting seasons of 1993, 1994, and 1995 (Lyon and Burcham 1997). Elk hunters carried GPS receivers that recorded a location every 15 seconds. Records of 99 hunting expeditions provided information about time spent hunting, movement speeds, time spent on and off roads, distances moved by hunters, and the classes of vegetation in which hunting takes place.

The Blackfoot Block Management Area is a hunting-season road closure unit with trailhead access points located at gates. Twelve trailheads were sampled during three hunting seasons for a sample of 684 observations of vehicles on 71 different days (Weber 1996). The average number of hunters per vehicle ($\underline{x} = 1.84$, $\underline{n} = 154$) was used to provide a daily estimate of hunter numbers entering at each trailhead.

In addition to observing hunters walking from trailhead on a daily basis, we compiled records for hunting camps inside the walk-in area. Each year we recorded 7 to 10 small camps, with 3 to 5 hunters per camp, remaining inside the area from a few days to two weeks.

ESTIMATING HUNTER DENSITY

Lyon and Burcham (1997) reported 93 elk hunting expeditions for which it was possible to determine the maximum daily departure distance from starting point. They showed that the maximum distance from trailhead increases as a function of the percentage of time spent on closed roads. We have summarized the original data to show the numbers and the percentage distribution of hunters in 500 m bands from the trailhead or starting point (Table 1). For every 100 hunters entering a walk-in area, only 86 will penetrate further than 1.0 km. At 1.5 km, another 15 hunters will have turned back, and at a distance of 5.0 km only 5 of the original hunters will be present.

In western Montana, nearly 12 % of all hunting effort for a 35-day season occurs on opening day (Henderson 1996) (Appendix C). This hunting pressure represents about 150 % of the highest effort for any other single day. In calculating hunter density estimates for the Blackfoot BMA, we used the average numbers of vehicles recorded on opening day (Table 2) as the best estimate of highest hunter densities during the season. Using the conventional method, we can calculate that 165.6 hunters in 243 km^2 will produce a hunter density of 0.68 hunters/km^2. However, this estimate supplies no distributional information and is misleading because only 5 % of all hunters leaving trailheads will penetrate more

Table 1.- Hunter numbers at 500 m intervals from start point, and resulting percentage distribution of hunter density.

	Maximum distance reached (km)									
Hunters	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**>5.0**
Number	93	80	66	56	44	31	21	16	11	5
Percent	100	86	71	60	47	33	23	17	12	5

Table 2.-Numbers of vehicles and hunters, opening day, at each of 12 trailheads, Blackfoot Block Management Area, 1993-1995

	Vehicles each year			Averages	
Trailhead	**1993**	**1994**	**1995**	**Vehicles**	**Hunters[a]**
Cap Wallace	9	10	1	6.7	12.3
Sunset Hill #1	11	20	13	14.7	27.0
Sunset Hill #2	5	9	11	8.3	15.3
Blackfoot River	3	5	6	4.7	8.6
Main Chamberlain	35	30	36	33.7	61.9
East Chamberlain	7	16	11	11.3	20.9
N. Fork Elk Creek	1	4	3	2.7	4.9
Yreka	0	1	5	2.0	3.7
Chamberlain Burn	3	0	0	1.0	1.8
Wales Creek	1	2	0	1.0	1.8
Upper Pearson Creek	0	1	7	2.7	4.9
Granite Mtn. Road	0	0	4	1.3	2.5
				Totals for opening day	165.6
				Comparable totals for Weekend days	69.8
				and Week days	27.3

[a] Average number of hunters per vehicle was 1.84

than 5 km from the trailhead. In addition, the interior of the Blackfoot BMA is a relatively popular location for hunting camps. During the three years of this study, we recorded an average of 9 camps containing 32 hunters on opening day. In effect, 32 of the hunters recorded at trailheads were already established at an average distance of 3.9 km from the nearest trailhead.

At the most used trailhead, we recorded an average 62.0 hunters on opening day with 46 starting at the trailhead and 16 located in 5 camps accessed from the trailhead. For each of the 12 trailheads and 9 camps a circle with a 1000 m radius describes the area utilized by all hunters entering at the point. A second circle, with radius 1500 m, describes a 500 m strip in which hunter density includes only 86 % of those at the starting point. A further 500 m strip will include only 71 % of the starting hunters.

Continuation of this exercise for 12 trailheads and 9 camps and the overlapping radii is relatively complex even with computer aided GIS. However, we found it extremely useful in developing a meaningful examination of the relationships between hunter density and elk vulnerability. We found, for example, that hunter densities on opening day exceeded 5.0/km^2 on 47.6 km^2 of the Blackfoot BMA, while 59.3 km^2 received less than 0.5 hunter/km^2. Overall, nearly 30 % of the area sustained hunting pressures lower than our original estimate of 0.68 hunters/km^2.

We also estimated the theoretical potential of restricting hunting camps as a means of reducing elk vulnerability. If all 165.6 hunters were required to hunt from trailheads, the area used by less than 0.5 hunters/km^2 would increase to 102.9 km^2 and nearly 48 % of the

area would receive hunting pressure lower than our original estimate of 0.68 hunters/km^2.

DISCUSSION: REDUCING ELK VULNERABILITY

The significance of this information is apparent in two ways. First, it establishes that most of our current data-manipulation techniques result in overestimates of the site specific daily hunting pressure exerted on elk populations. Such estimates are particularly high for large geographic areas. In attempting to control elk vulnerability, we can ill afford to assume a hunter density of 1.0 hunter/km^2 is acceptable if a site specific hunter density of 0.5 hunters/km^2 produces an excessive bull harvest. Second, it appears that elk vulnerability can be reduced by managing the size of road closure units to achieve site specific reduced hunter densities.

In view of the probable overestimates of site specific hunter density, we suggest that any hunter density in excess of 1.0 hunter/km^2 is likely to produce excessive harvest of available elk. Where this is not the management objective, vulnerability will be reduced if at least 1/3 of the habitat can be managed to have less than 0.5 hunter/km^2 hunting pressure. In building a theoretical projection of hunter densities, we have concluded that an empirical solution using GIS may have the broadest application. Using an outline of the proposed walk-in area, a manager can identify potential trailheads and campsites as points, and buffer each point with a circle of 5000 m radius. The area thus inscribed will sustain nearly 95 % of the hunting pressure. If the area remaining will sustain 5 % of the expected hunters at a density less than 0.5 hunters/km^2, and if that area represents over 1/3 of the total, the walk-in is probably of adequate size. Just as important is recognition that failure to meet these

standards may create an undesirable vulnerability situation.

When this method is used to estimate the minimum size walk-in area capable of providing bull escapement without reducing hunter recreation opportunity, the manager should recognize that size alone may not provide adequate security. It seems obvious, for example, that vulnerability is unlikely to be reduced in an area that provides inadequate security cover.

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Chapter 7

IDENTIFYING LANDSCAPE ELEMENTS IN RELATION TO ELK KILL SITES IN WESTERN MONTANA

IDENTIFYING LANDSCAPE ELEMENTS IN RELATION TO ELK KILL SITES IN WESTERN MONTANA

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Abstract: The landscape elements that influence elk (*Cervus elaphus*) vulnerability during hunting season were studied in the Chamberlain Creek area of western Montana from 1993-1995. Nine GIS coverages were used in PC Arc/Info and MAYA to describe 84 elk kill sites, 267 live elk locations, and 166 random points, at three scales (site specific, 200 m, and 700 m radii (15.2 ha and 155.2 ha respectively)). Discriminant function analysis (DFA) was used to differentiate among three point groups (elk kill sites, live elk locations, and random points) using 4 road variables, 1 hydrography variable, 24 vegetation classes, 4 vegetation-change classes, an index of fragmentation, and 3 topographic variables. At each scale examined, a variable was used which describes some aspect of road proximity or road density. In addition, a vegetation-change variable and two vegetation classes (lodgepole pine and open Douglas-fir vegetation classes) were used to achieve maximal differentiation of the groups ($\underline{x}$ = 50% correct classification). These variables were examined in detail to understand their importance to elk ecology.

Elk kill sites could not be differentiated from random points, but locations of live elk were readily differentiated from elk kill sites and random points. Elk selected particular elements of the landscape which 1) were not in close proximity to open roads, 2) had low road densities, and 3) contained forested cover in large patches which had not sustained a timber harvest treatment within the past 10 years, and provided substantial hiding cover. This summary does not describe security areas that are independent of other influences, however. With sufficient hunting pressure any elk will be vulnerable in any type of cover. Further, elk security is dynamic and based ultimately on moment-to-moment decisions and reactions by the animal. Therefore, security areas must meet not only cover and topographic requirements, they must also be large enough to ameliorate the effect of concentrated hunting pressure.

Keywords: ***Cervus elaphus*, elk, GIS, habitat, hunting, landscape, mortality, security, and** vulnerability.

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INTRODUCTION

A current problem for elk biologists involves several aspects of elk vulnerability during the hunting season. Management of elk harvest in Montana has involved controlling the length of the season and allowing permit hunting of cows. A liberal bull harvest has been retained. One result has been a decline in the number of mature bulls remaining after the hunting season. Today, as is the case in Oregon, some elk herds have distorted population structures (Leckenby et al. 1991) that deviate substantially from public expectations and may be biologically unsound (Squibb et al. 1991, Prothero et al. 1979).

Lyon and Canfield (1991) studied habitat selection by elk before and during the rifle season in Montana. In that study, habitats were examined under a test hypothesis that survivors had made appropriate selection for survival. Other than the expected negative correlation with road density, nothing in habitat structure was detected as important to hunted elk at the site specific scale. However, landscape level selection for large patches was detected.

An elk vulnerability symposium, held in 1991 at Montana State University examined many facets of elk vulnerability and produced a state-of-the-knowledge compendium for the complex situations involving elk and their habitats during the hunting season (Christensen et al. 1991). Among many papers presented, Leptich and Zager (1991) demonstrated that elk mortality was higher where road densities were higher and that a bull elk in an area with high road density ($\geq$ 9.5 km of road/ km^2 ($\geq$ 5.9 miles of road/ mi^2)) has virtually no probability of surviving to age five. Vales et al. (1991) showed that hunter densities are an important component of vulnerability. Their data indicate that any situation where hunters outnumber legal bulls is certain to produce distorted post season bull:cow ratios. In the Clearwater drainage of Idaho, Unsworth and Kuck (1991) studied bull elk vulnerability and habitat use by comparing mortality in roaded and unroaded portions of their study area. Annual survival rates of bull elk in roaded areas were significantly lower than in unroaded areas.

Previous elk research in the Chamberlain Creek area includes a 9 year study completed by Marcum et al. (1984), a pellet transect study identifying elk habitat selection (Scott 1978), a radio telemetry study of elk habitat selection (Lehmkuhl 1981), an investigation of elk heart rate and activity patterns (Lieb 1981), short term changes in elk distribution (Edge 1982), and a habitat selection study using multivariate statistical techniques (Edge et al. 1987).

The goal of my research was to examine the sites where elk were harvested by hunters, and to assess the vulnerability and security of elk in relation to various landscape elements such as vegetation and topography. Specific objectives of this study were to evaluate the interaction of landscape and habitat variables influencing elk vulnerability during the hunting season, provide information for wildlife and land managers to enable them to design landscapes to better manage elk vulnerability, and provide some basic insight into the variations in elk habitat selection corresponding to changes in landscape characteristics.

I examined habitat selection by elk that were killed, and the selections made by live, radio-collared elk. Although many other factors were involved, the test hypotheses presumed that any animal killed made an error in security selection. Locations of kill sites were compared with random samples and with security selections made by live elk during the same time period. This study tested the following specific hypotheses:

H_0 : Habitats at kill sites were not different than habitats used by live radio-collared elk during the hunting season.

H_A : Habitat use by live radio-collared elk during the hunting season differed from habitat use by elk that were killed.

H_0 : Habitats at kill sites were not different than randomly selected habitats.

H_A : Habitats at kill sites differed from randomly selected habitats.

H_0 : Habitats used by surviving elk were not different than randomly selected habitats.

H_A : Habitats used by surviving elk differed from randomly selected habitats.

Study Area Description

The Chamberlain Creek study area lies approximately 56 km (35 mi.) east of Missoula, Montana in the northern Garnet Mountains (Fig. 1). The study area is roughly circumscribed by the Blackfoot River to the north, Elevation Mountain to the south, Dunigan Mountain to the east, and Morrison Peak to the west. The home ranges of at least two non-migratory elk herds (Marcum et al. 1984) are contained in this area.

Public land in the study area is managed by the Bureau of Land Management, Montana Department of State Lands, and The University of Montana's Lubrecht State Experimental Forest. Plum Creek Timberlands LP owns most of the private forest land. A number of other areas are under private ownership.

Elevations within the 259 km^2 (100 mi^2) study area range from 1,140 m (3,740 ft.) to 2,156 m (7,073 ft.). Slopes vary from gentle, nearly level (< 5%) along the valleys and ridgetops, to steep (> 60%) on some of the hills and mountains. Precipitous slopes occur along the north face of Blacktail Mountain. Hot, dry summers are typical, with the majority of precipitation falling as snow in winter. These conditions give rise to primarily xeric vegetation types. Open areas are dominated by grasses. Six major tree species occur in forested areas: ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and sub-alpine fir (*Abies lasiocarpa*). Lodgepole pine and sub-alpine fir are restricted to higher elevation sites, whereas ponderosa pine is found at lower elevations.

Much of the study area has been logged in the past 20 years, especially the lower

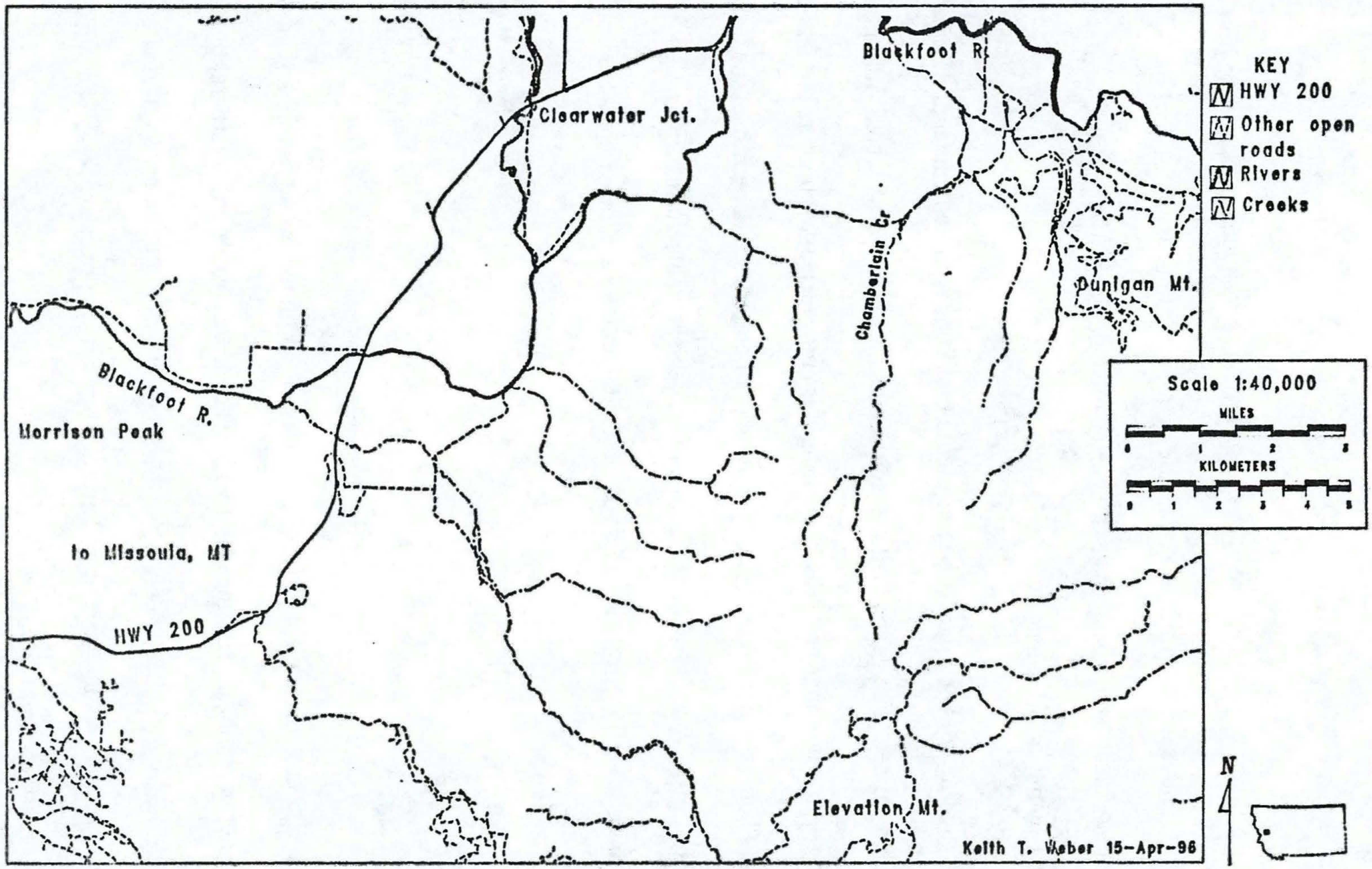

Figure 1. Map of the Chamberlain Creek study area

elevation foothills. Cattle ranching and grazing were moderate. Agriculture was limited to production of alfalfa (*Medicago sativa*) at lower elevations.

The primary recreational use of the study area is sport hunting. However, horse-back riding occurs, and some sportfishing and canoeing access points exist. As part of the Blackfoot Special Management Area, many roads are closed to vehicular traffic between September 1 and December 1 by the use of gates.

Elk hunting season typically begins on the first Sunday in September and ends on the last Sunday in November. The general rifle season occurs during the last 5 weeks of hunting season, preceded by a bow-hunting-only season. During this study (1993-95) hunters possessing a valid license could harvest any antlered bull. The number of antlerless elk permits issued by Montana Department of Fish, Wildlife and Parks remained relatively stable during my study. In 1993 and 1994, 250 antlerless elk permits were issued while 200 antlerless elk permits were issued in 1995.

METHODS

GIS Coverages

Nine GIS coverages were used for my study. Four point coverages (elk kill sites, live elk locations, random points, and trailheads), two line coverages (roads and hydrography), and three polygon coverages (existing vegetation, vegetation-change, and hunter density). Topography was incorporated into the existing vegetation coverage by using majority aspect, mean slope, and mean elevation for each polygon.

Elk Kill Sites: Three methods were used to determine elk kill sites; contacting hunters at the Bonner game check station, interviews with hunters who had killed an elk, and evidence found in the field. Hunters who had killed an elk in hunting district 292 (or in that part of hunting district 283 south of the Blackfoot River (Fig. 2)) were interviewed and asked to indicate on a map the exact site where the elk was initially shot and where the viscera were located. Using this information, a search was conducted to locate the remaining viscera of the elk and record the location of the kill site using a global positioning system (GPS) receiver. The GPS units (Garmin GPS100 SRVY) were considered accurate to +/- 50 m (164 ft.) using a 2 minute running average (Garmin 1992). This technique continuously updates the position until the averaging session is completed. These positions were not differentially corrected.

I estimated the age of all elk killed in the study area using tooth wear and replacement (Quimby and Gaab 1957). On several occasions elk were brought to the game check station in quarters, and the age of these animals was recorded as unknown. In other cases, some hunters who had harvested older bull elk (often considered trophy animals) requested that their elk not be aged as the aging technique involves cutting the hide from the cheek to expose the mandibular dentition, thereby destroying the appearance of the hide. In this situation, the age of the animal was estimated by the size and mass of the antlers.

Live Elk Locations: Aerial telemetry flights were performed once or twice per week throughout the hunting season to locate approximately 30 radio- collared elk (Appendix A). Sex and age of the animal, and Universal Transverse Mercator (UTM) coordinates identifying each point were recorded to the nearest 100 m (328 ft.).

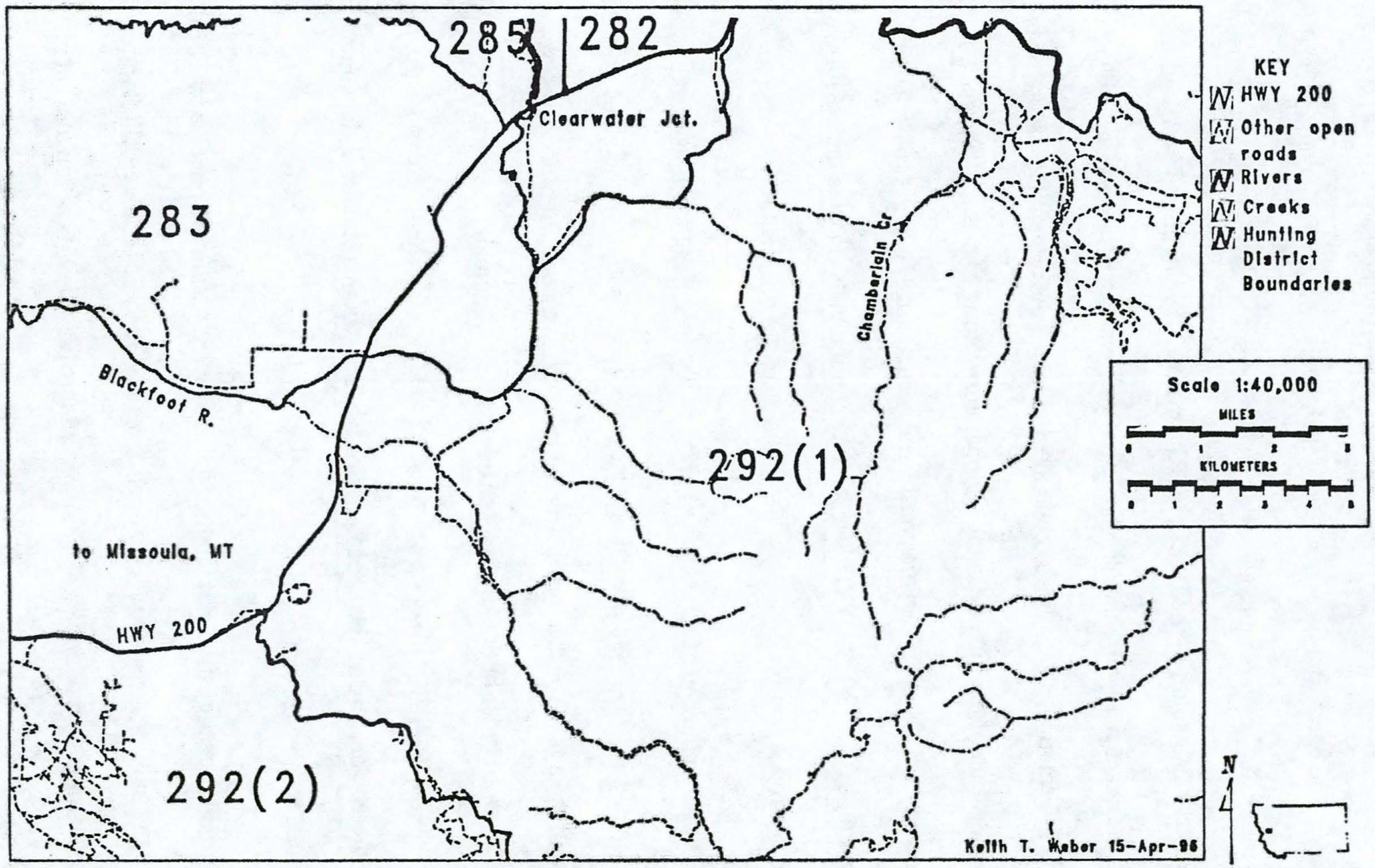

Figure 2. Map of hunting district boundaries.

Elk kill sites and live elk locations on land closed to public hunting were removed from the sample to eliminate the potential bias produced by these areas. These elk were not available to the average hunter and may not have responded to hunting pressures that influenced the habitat and security selections made by elk on forested lands that were open to the general public.

Random Points: To reliably approximate available habitat (cf. Thompson 1987), 1,200 random points were generated by computer. Statistical testing required that the sample of random points be comparable in number to the sample of elk kill sites and live elk locations (Norusis 1990), therefore a randomly selected subset of the original 1,200 points was used (n = 166). A use-availability approach was employed to test the efficacy of this random sampling scheme using Chi-square (Neu et. al 1974, Byers et al. 1984). I compared the relative percent each vegetation class was identified by a random point (use), with the relative percent of the area occupied by each vegetation class (availability), and found no difference between the frequencies of sampled vegetation and available vegetation ($P < 0.05$, Table 1). Further, the subset of 166 random points sampled the available vegetation as accurately as the 1,200 random points. UTM locations were used to create point coverages in PC ARC/INFO for all elk kill sites, live elk locations, and random points.

Trailheads: The study area, part of the Blackfoot Special Management Area, was designated a walk-in only hunting area. Although mountain bikes and horses were allowed, commercial outfitting was prohibited. Hunters wishing to use the study area entered any of 11 parking and access sites (i.e., trailheads), located at low elevation foothills (approx 1,140 m (3,740 ft.)). The trailhead coverage was created using PC ARC/INFO. The proximity of each

Table 1. Chi-square test of random sampling efficiency

Vegetation class	Observed[a]	Expected[b]	Chi-value
Urban industrial	0.6	0.4	0.1
Cropland/ pasture	0.0	0.4	0.4
Irrigated crops	1.8	2.4	0.1
Rangelands	0.6	1.4	0.4
Foothills/ parklands	10.9	7.5	1.6
Disturbed grasslands	1.2	1.2	0.0
Other herbaceous	10.9	8.2	0.9
Mesic upland shrub	0.0	0.1	0.1
Xeric upland shrub	0.0	0.0	0.0
Sagebrush	3.0	2.8	0.0
Mixed grass/ shrub	0.0	1.0	1.0
Other shrub	0.0	0.2	0.2
Broadleaf forest	0.0	0.0	0.0
Spruce forest	0.0	0.0	0.0
Lodgepole pine	10.9	12.4	0.2
Ponderosa pine	4.2	4.5	0.0
Douglas fir	20.6	21.5	0.0
Western larch	2.4	1.1	1.5
Mixed coniferous	15.2	17.2	0.2
Open Douglas fir	15.8	15.5	0.0
Regenerating clearcut	1.8	1.9	0.0
Lakes/ water	0.0	0.6	0.6
Wet meadows	0.0	0.0	0.0
	Chi-square		7.4
	n =		23
	d.f.		22
	critical Chi-value (0.05)		35.17

[a] observed values are the relative percent of each vegetation class identified by the random point sub sample.

[b] expected values are the relative percent of each vegetation class found in the supervised vegetation coverage.

point (elk kill site, live elk location, and random point) to the nearest trailhead was determined using PC ARC/INFO (NEAR).

Roads: This coverage was created using United States Geological Survey (USGS) 7.5' topographic series maps (1:24,000 scale) and aerial orthophotography (1:24,000 scale). The coverage was edited annually to include new roads, correct errors, and update road status information. Road status for motorized traffic was coded as 1) open all year, 2) closed seasonally (September 1 - November 30), 3) closed all year, or 4) not traversable. The road coverage was used to determine the proximity of each point (elk kill site, live elk location, and random point) to any road, and to open roads only.

Hydrography: This coverage was obtained from the Montana Department of Fish, Wildlife and Parks (1:24,000 scale), and was used to determine the proximity of each point (elk kill site, live elk location, and random location) to streams or rivers. The hydrography coverage did not include wet micro-sites which could have been adequate to satisfy an elk's demand for water.

Existing Vegetation: Landsat Thematic Mapper (TM) digital coverages and maps were used to identify different vegetation classes within the study area. Polygons were created by unsupervised classification and sampled in the summer of 1994 by ground-truthing.

Thematic Mapper samples vegetation by recording the amount of light reflected from the earth's surface at a variety of wavelengths. Pixel size is 30 m (98 ft.) when using TM bands 1-5 and 7 (Barrett and Curtis 1992). These bands sample wavelengths from 0.45-2.35 *u*m (Table 2). The frequency of each spectral class assigned by the unsupervised classification was used to

determine sampling frequency for ground truthing. Spectral classes representing < 1% of the study area were sampled once. All other spectral classes were sampled a minimum of five times. Each 7.5' topographic map contained no less than 30 vegetation samples. The criteria used to select sample sites were; 1) no sample point could be within 70 m (230 ft.) of a polygon's edge, and 2) the sample point appeared representative of the entire polygon.

Several independent variables were measured or described for each sample site. These variables are listed below with units of measure and precision where appropriate:

Geographic Location of the sample in latitude/ longitude, UTM, and Public Land Survey System (PLSS) validated by GPS.

Elevation, determined from 7.5' maps within the nearest 12.2 m (40 ft.) contour interval.

Slope, degrees using a clinometer.

Aspect, degrees using a compass.

Overstory Canopy Cover estimated to the nearest 5%

Canopy Closure attributable to each overstory species was estimated.

Stand Structure based on DBH size classes for trees < 25 mm (< 1 in.), 25-125 mm (1-5 in.), 125-225 mm (5-9 in.), 225-525 mm (9-21 in.), and > 525 mm (> 21 in.).

Vegetation Land Classification (Hart 1994)

Cover Type (Society of American Foresters (SAF))

Habitat Type according to Pfister et al. (1977).

Basal Area, measured using a 5 BAF prism.

Table 2. Thematic Mapper Sampling Bands and their applications (Barrett and Curtis 1992)

Band	TM Wavelength	Application
1	0.45-0.52	Soil/ Vegetation differentiation
2	0.52-0.60	Green reflectance by healthy vegetation
3	0.63-0.69	Plant species differentiation
4	0.76-0.90	Biomass survey
5	1.55-1.75	Vegetation moisture
7	2.08-2.35	Vegetation moisture and geologic mapping

Overstory Species present in descending order of prevalence (Hitchcock and Cronquist 1973, Patterson et al. 1985, Nelson 1992).

Mean DBH for each overstory species.

Basic Stand Structure as grass/forb, low shrub, saplings, poles, mature trees, old growth forest, and/or snags if the structure class can be considered a significant part of the site.

Dominant Tall Shrub Understory species > 1.2 m (> 4 ft.).

Percent Composition of the tall shrub understory, estimated as < 25%, 25-50%, or > 50%.

Understory species, the most abundant species and estimated percent cover.

Hiding cover, how well elk could be seen at a distance of 61 m (approximately 200 ft.), as either visible all the time, some of the time, or never visible (cf. Skovlin 1982).

Difficulty of travel, based on the amount of dead-fall and classified as either easy, pick your way, or struggle.

Using these data from 242 vegetation ground-truth samples, the University of Montana, Wildlife Spatial Analysis Laboratory produced a supervised classification of the study area using methods similar to those described by Hart (1994). Relative frequencies for the 24 vegetation classes are given in Fig. 3. Canopy and hiding cover estimates associated with the vegetation classes were summarized using ground-truth data (Table 3 (cf. Appendix D)).

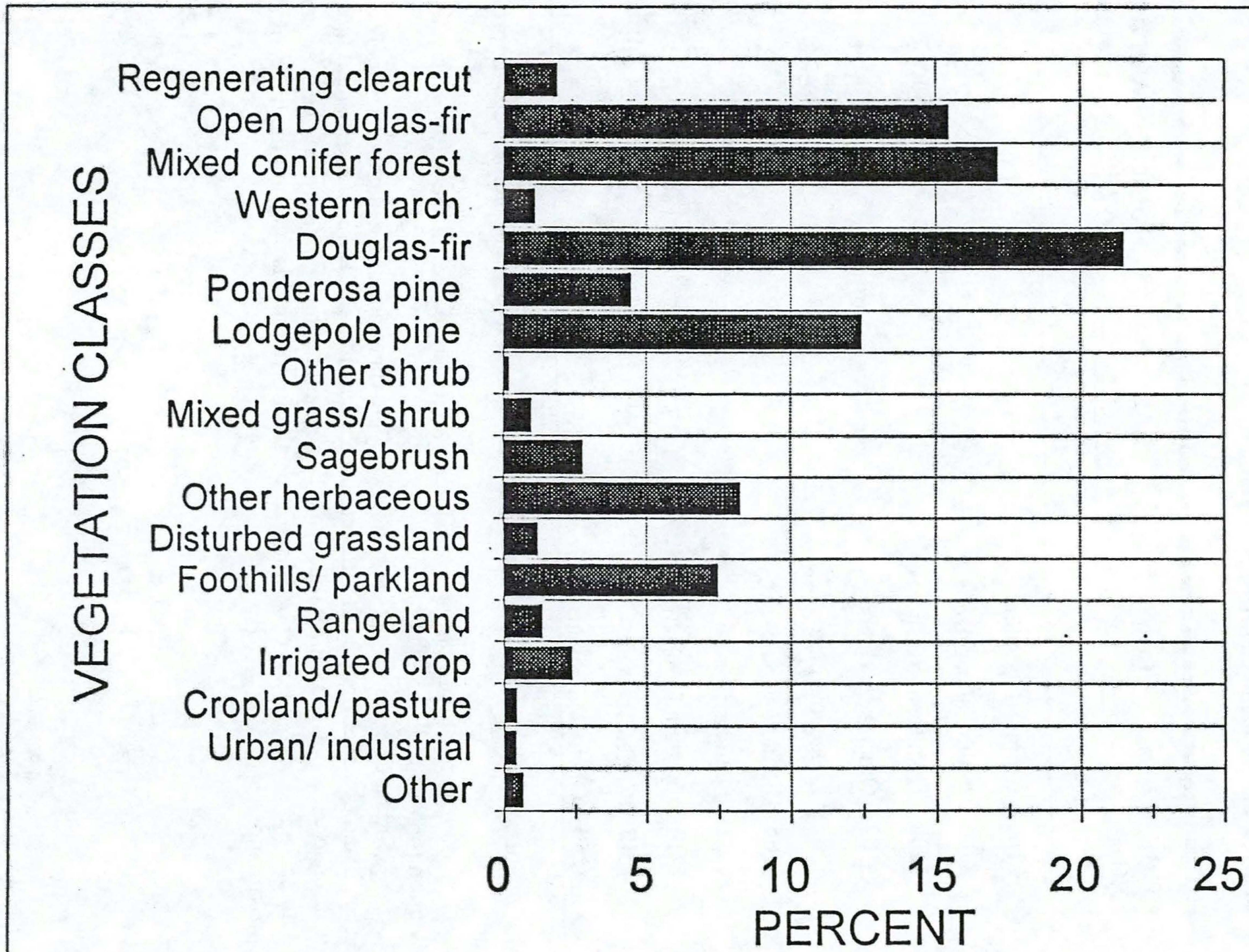

Figure 3. Distribution of vegetation classes in the study area

Table 3. Measured parameters associated with some vegetation classes

CODE NO.	CLASS	CANOPY[a] MIN	CANOPY[a] MAX	HIDING COVER[b]	SAMPLES (n =)
2101	Cropland/ pasture	0	2	1.0	5
3101	Foothills/ parklands	1	19	1.3	14
3102	Disturbed grasslands	5	18	1.1	10
3103	Other herbaceous	1	16	1.5	40
4202	Lodgepole pine	39	85	2.7	24
4205	Ponderosa pine	19	43	1.8	4
4211	Douglas fir	48	78	2.5	48
4214	Western Larch	17	67	2.0	6
4217	Mixed conifer	38	76	2.4	67
4250	Open Douglas fir	23	31	1.8	8

Notes: This table was created using field measured data obtained during ground-truthing.

[a] % Canopy minimum and maximum values are based on the mean +/-1 standard deviation (66%confidence level).

[b] Hiding cover estimates are subjective approximations of the likelihood that elk could be seen by an observer (located at the center of a vegetation plot) from a distance of 200 feet. The discrete values ranged from 1 (elk could be seen all the time), 2 (elk could be seen part of the time), to 3 (elk could never be seen). The values given in this table are the mean of these approximations.

Vegetation-Change: The vegetation-change coverage was created by comparing waveband 7 (cf. Table 2) on a TM image recorded in 1992 with one recorded in 1984. Increasing soil reflectance values (detected by waveband 7) indicates a loss of vegetation, while decreasing soil reflectance values indicates a gain or regrowth of vegetation. This coverage was used in my analysis because sites where vegetation was lost presumably increased the elk sightability distance and the area of a hunter's viewshed. This could have a direct influence on elk mortality and habitat selection. The four vegetation-change classes created were adjusted to match areas of known vegetation-change. They were:

1- No vegetation-change: This class represents those polygons with no tangible changes in the landscape.

2- Intermediate Vegetation Loss: This class represents shelterwood and selection harvest treatments that occurred between 1984 and 1992.

3- High Vegetation Loss: This class represents clear cut, and seed tree harvest treatments that occurred between 1984 and 1992.

4- Gained Vegetation: Polygons with > 10% of their area having increased vegetative cover.

Hunter Density: A hunter density map was created for the Blackfoot Special Management Area (a walk-in area). This was accomplished using the trailhead coverage, data from trailhead use sampling, and hunter-GPS routes (Lyon and Burcham 1995). Most trailheads were sampled daily throughout three hunting seasons (1993-95) (Appendix C). The number of vehicles parked at each trailhead was recorded, as was the number of hunters per vehicle when

known. Eleven trailheads were sampled yielding 684 trailhead use observations.

The mean plus one standard deviation (66% confidence interval) of the maximum distance travelled by a hunter from a trailhead (*n* = 93 routes) was used to create a buffer polygon around each trailhead point using PC ARC/INFO (BUFFER). The extent of each trailhead-polygon was cropped to eliminate those areas where hunters were unlikely to enter (e.g., land closed to public hunting and safety zones). This resulted in each trailhead-polygon having a unique size. Trailhead use data (*n* = 71 days) allowed me to assign hunter frequency values to each trailhead-polygon. This was estimated by multiplying the mean number of vehicles at each trailhead with the mean number of hunters per vehicle ($\underline{x}$ = 1.8; *n* = 154 vehicles). After appending all trailhead-polygons into a single coverage, numerous polygons were found to overlap adjacent polygons creating new polygons that could theoretically contain hunters from more than one trailhead. Hunter use of the area encompassed by a given polygon was assumed to be evenly distributed across the available landscape. The number of hunters within a polygon was found by (cf. Fig 4):

$$Nh_i = \Sigma\ [(H_n(\text{total}) / TA_n(\text{total})) * PA_i]$$

Where;

NH = the total hunters included in the polygon.
H_n(total) = the number of hunters entering the polygon from a given trailhead.
TA_n(total) = the area of the complete trailhead-polygon in km^2
PA_i = the area of an individual polygon in km^2.
n = identifies a specific trailhead.
i = identifies a specific polygon.

note: The contribution of each trailhead (n) to the specific polygon(i) is summed to give the total number of hunters included in the polygon (NH) (Table 4).

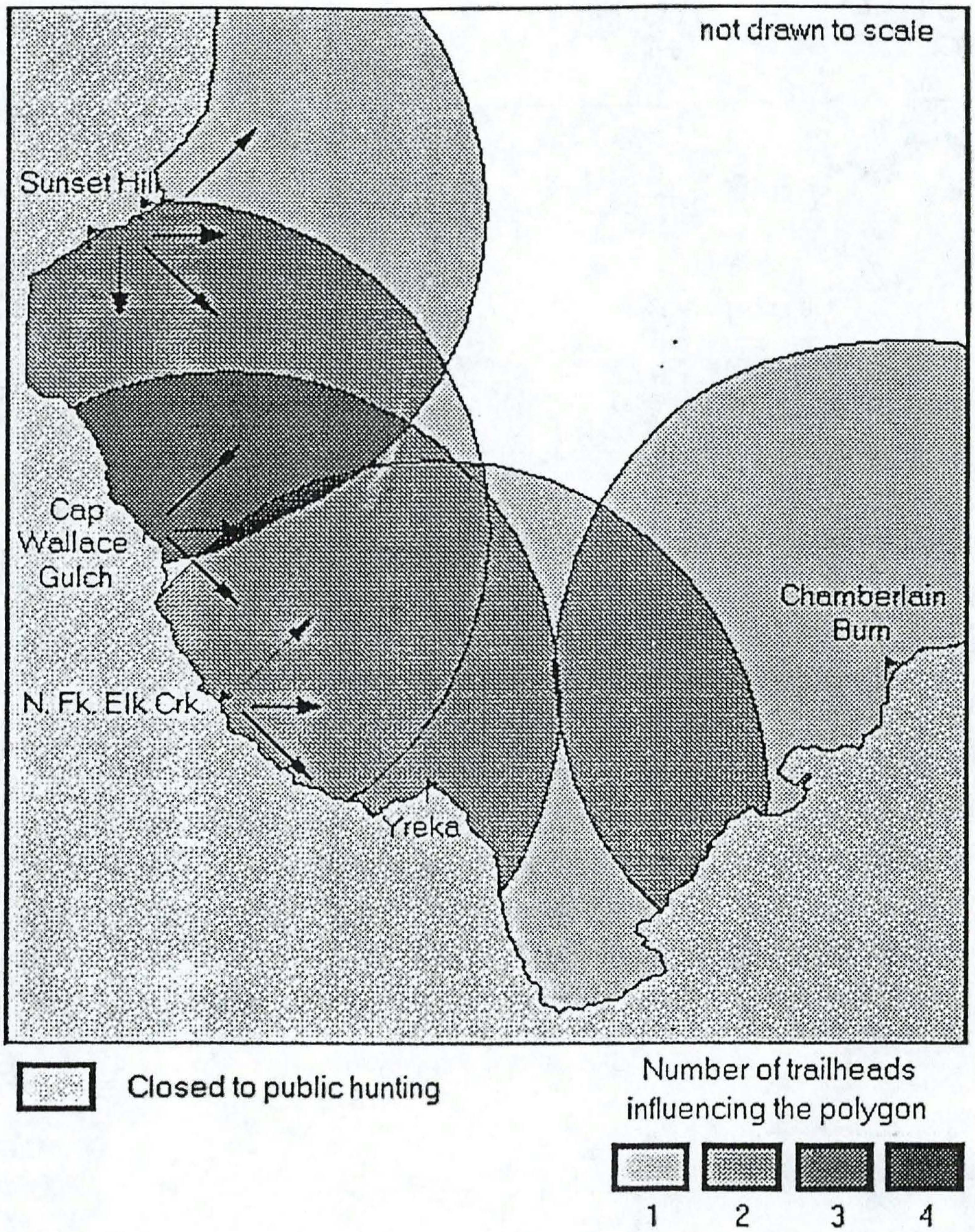

Figure 4. Illustration of hunter density modelling.

Table 4. Hunter use and densities in the study area

Trailhead no.	Trailhead Name	Mean no. hunters[a]	Hunter density per km^2
1	Cap Wallace	13.6	0.44
2	N. Fk. Elk Creek	2.6	0.10
3	Yreka	3.2	0.09
4	Chamberlain Burn	1.2	0.03
5	Wales Creek	1.2	0.02
6	Sunset Hill	18.5	0.58
7	Blackfoot River	5.9	0.25
8	Chamberlain	34.1	0.63
9	E. Fork Chamberlain	8.3	0.23
10	Pearson	6.7	0.20
11	Granite Mt.	5.5	0.27

[a] - mean number of hunters per day was based on weekend use of the study area.

Hunter density (HD) for a given polygon was found by:

$$HD_i = NH_i / PA_i$$

The hunter density at each point (elk kill site, live elk location, and random point) was found using PC ARC/INFO (IDENTITY).

Database Production and Statistical Procedures

Three databases were assembled for statistical testing (site specific, near, and far analysis). Each database contained three types of point locations (elk kill sites, live elk locations, and random points).

The site specific analysis database contained the following 10 variables: proximity to any road, proximity to an open road, proximity to water, proximity to the nearest trailhead, vegetation class, vegetation-change class, hunter density, elevation, slope, and aspect.

Point coverages were overlaid on the existing vegetation and vegetation-change coverages using PC ARC/INFO (IDENTITY) to determine the vegetation class, elevation, slope, aspect, and vegetation-change class at that point. Hunter density at each point was also determined using PC ARC/INFO (IDENTITY). Point proximities to an open road, to any road, to the nearest trailhead, and to water were determined using PC ARC/INFO (NEAR).

Near Analysis Database: The near analysis database contained a description of the landscape within a 200 m (656 ft.) radius of the point. Variables included in this database were the area of each vegetation class, and vegetation-change class, number of pixels of open and closed roads, and the number of non-road pixels (the rasterized road coverage contained 3 types

of pixels; open road, closed road, and non-road), and the total number of different vegetation classes encountered within the sampling perimeter (a measure of fragmentation). The area contained within the analysis perimeter was 15.2 ha (31.1 acres).

Far Analysis Database: The far analysis database contained a description of the landscape within a 700 m (2,297 ft.) radius of each point (selected to approximate short-term habitat availability). The same variables are included in this database as in the near analysis database. The area contained within the analysis perimeter was 125 ha (307.7 acres). To perform this analysis, vector coverages of vegetation, vegetation-change, and roads were rasterized using 30 m pixels. As a result, the actual area sampled was smaller than predicted when computing the area of a circle (e.g., area = $\pi * r^2$, $3.14 * 700^2$ = 154 ha (380 acres)). MAYA software (Glassy and Lyon 1989) was used to determine the number of pixels of each vegetation class, vegetation-change class, and road type within 200 and 700 m (656 ft. and 2,297 ft.) radii of each point.

Discriminant function analysis (DFA) was used to address the test hypotheses. Each DFA attempted to discriminate among three groups (elk kill sites, live elk locations, and random points). A step-wise procedure that maximized Wilks-lambda was used (i.e., the variable that provides the best discriminating ability is used by the DFA first). A second iteration was performed using a direct procedure with only the first two variables that were selected by the step-wise procedure. The resulting mean correct classification was 50%. A third iteration was performed with the direct procedure using variables that were not selected by the step-wise procedure but seemed biologically important. The resulting correct classification rate of the latter functions was very poor ($\underline{x}$ = 35%). The three groups (elk kill sites, live elk locations, and

random points) were tested together and in pairs. Each test was run several times, first using the full database, and then using 1 of the following 3 subset databases.

1) Because cow elk were harvested only by permit, data pertaining to cow elk were removed from kill sites and live elk locations. A hunter may have encountered a cow elk that could have been harvested, but because of hunting restrictions, and not security areas, the animal was not killed. Spike bulls (1.5 years-old) were also excluded because they tended to remain with cow herds and did not use the higher elevation, more heavily forested areas favored by older bulls. If cows and spike bulls responded to hunting pressure differently than adult bulls, this exclusion should have produced different classification results.

2) Radio-collared elk that did not survive the hunting season were excluded from live elk locations. If a given home range contained little or no security cover, elk living in this area may have had an increased probability of harvest, and the live locations obtained from such animals would have been indistinguishable from a kill site.

3) Both exclusion criteria described above were applied to create a third subset to analyze surviving adult bull elk only.

Each exclusion could improve the classification rate in several ways. First, the effect of the exclusion may reveal differences between certain biological classes of elk and hence, add to our knowledge of elk ecology. Second, improved classification may reflect reduced within-group variance due to smaller sample size. The statistical significance and validity of each exclusion was tested by comparing the exclusion groups with the remaining groups using an F-test.

Any DFA that tests groups with disproportionate sample sizes will contain a classification

bias for the group with the largest sample size (Norusis 1990). In essence, the disproportionate groups are subject to chance classification. To compensate for this, the resulting classification rates were corrected for the effect of chance using the Kappa statistic (Titus et al. 1984). Kappa values were reported as a proportion, indicating how each classification performed relative to chance alone (e.g., a Kappa value of 0.40 indicates that a classification performed 40% better than could be expected by chance). The Z-statistic was computed to determine the significance of the classification. Interpretation of the results was made by examining the classification rates, eigenvalue, F-test, Kappa, and Z-statistic.

RESULTS

Description and Summary of Points Used in the Study

During the 3 hunting seasons (1993-95), 257 elk kills were reported, and 125 of these were located in the field. Of those located, 41 were found on land closed to the general public (Table 5). A marked increase in live elk locations on land closed to the general public was observed in 1995 (Table 5). This was primarily a result of several ranches that allowed some hunting on their property during 1993 and 1994, but closed their ranches to hunting in 1995.

The mean age of elk killed (and aged) in the study area was approximately 2 years for bulls, and approximately 3 years for cows (Table 6). Forty-nine percent of the bulls killed in the study area were 1.5 years-old. The number of bulls killed during the first week of the hunting season was approximately equal to the total number of bulls killed during the remaining four weeks (Fig. 5). In comparison, the age of cows killed in the study area was relatively uniform.

A summary of the points used in the DFA was prepared to describe each elk kill site, live

Table 5. Status of reported elk kill sites and recorded live elk locations

	1993	1994	1995	Total
Elk kill sites				
Included in the DFA	20	38	26	84
Not found	52	52	28	132
Closed to general public	5	20	16	41
Total	77	110	70	257
Live Elk locations				
Included in DFA	92	95	93	267
Closed to general public	25	21	73	119
Total	117	116	166	399

Table 6. Summary of elk harvested in the study area 1993-95[a]

Age Class	Cows (%)	Bulls (%)
0.5	23	7
1.5	17	49
2.5	8	25.[b]
3.5	19	9
4.5	18	7.[b]
5.5	8	2
6.5	3	0
7.5	1	0
8.5	3	1.[b]
9.5	1	0
$\bar{x}$ =	3.06	2.20
Minimum	0.50	0.5
Maximum	9.50	5.5
n =	78	121

[a] includes all elk killed and aged, not just those used in the DFA.
[b] includes some elk that were aged based on antler characteristics.

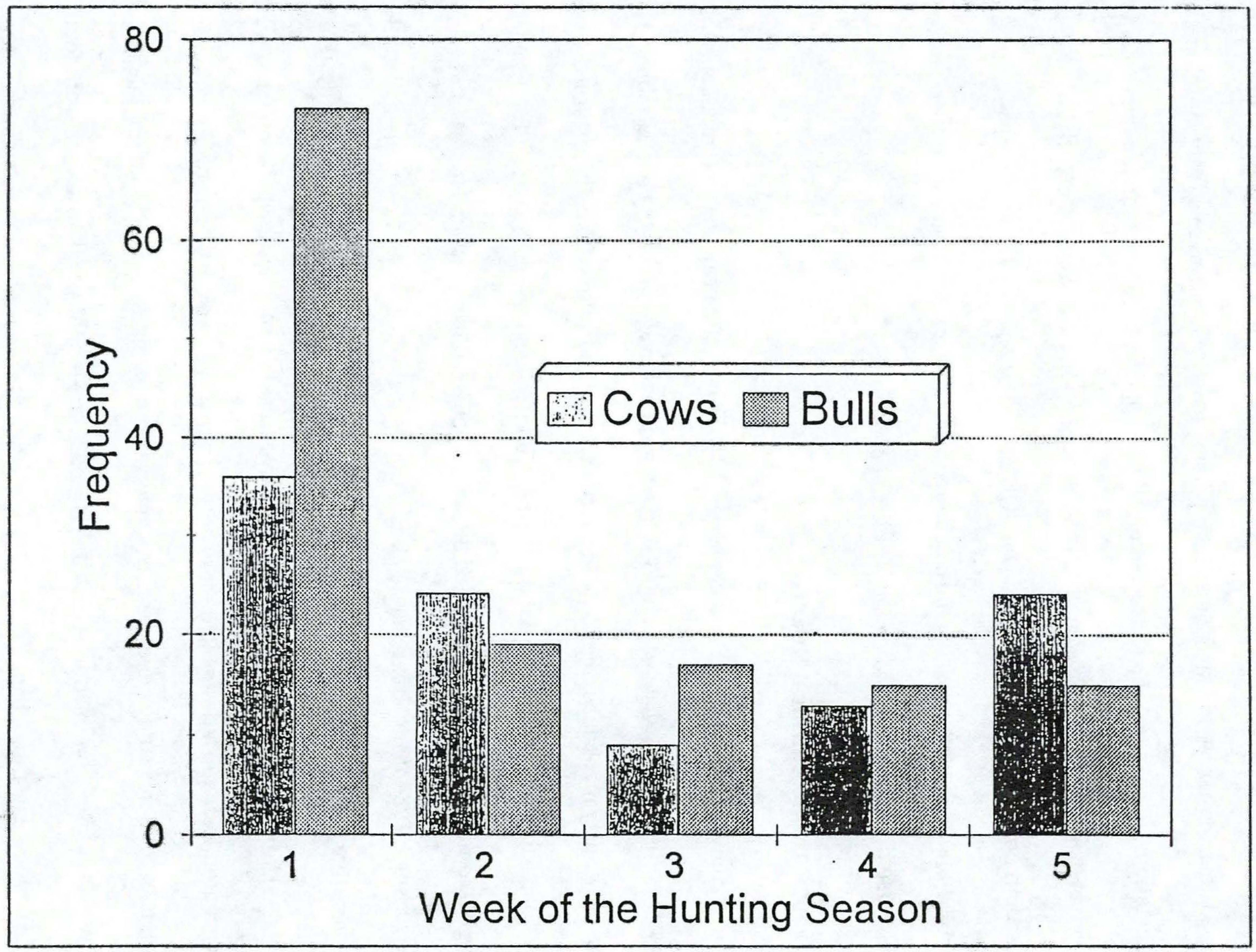

Figure 5. Weekly summary of elk harvest

elk location, and random point (Table 7). Comparing proximity to open road measurements revealed that live elk locations were found, on average, 1,000 m (3,281 ft.) farther from open roads than either elk kill sites or random points. However, due to relatively large standard deviations, when a 66% confidence interval was applied, each measurement was found to exhibit a great deal of overlap between groups. The vegetation class where most elk kill sites and random points were found was the *Douglas-fir vegetation class* (20% of both elk kill sites and random points), which was the most common vegetation class. Live elk locations were typically associated with the *lodgepole pine vegetation class* (52%).

Biological and Statistical Results

The site specific database contained 10 variables and provided an overall correct classification of 53% using *proximity to open road* and *vegetation-change* variables (Table 8). As previously mentioned, the mean distance of live elk locations from an open road was found to be approximately 1,000 m farther than either elk kill sites or random points (Table 7). The *vegetation-change* variable identified those polygons that had sustained losses in vegetative cover since 1984 using four discrete classes (polygons with a vegetation-change classification of 1 were those areas that had sustained no vegetation-change, a classification of 2 designated a polygon with intermediate vegetation loss, a classification of 3 designated a polygon with high vegetation loss, and 4 designated those polygons that had exhibited gained vegetation). All points used in this study were ordinarily associated with areas of no vegetation-change (class 1). However, closer examination revealed that while 95% of all live elk locations were found in areas of no vegetation-change, only 60% of elk kill sites were found in these areas. Further, 35%

Table 7. Summary of sites used in the discriminant function analysis

	Proximity to any road	Proximity to an open road	Proximity to water	Vegetation class
Elk Kill Sites (*n* = 84)				
Mean	192	1,540	356	
Median	142	1,085	315	Douglas fir
Standard deviation	194	1,486	234	
Standard error	21	162	26	
Minimum	0	9	1	
Maximum	939	5,646	911	
Live Elk locations (*n* = 267)				
Mean	315	2,545	465	
Median	231	2,527	450	lodgepole pine
Standard deviation	273	1,405	287	
Standard error	17	86	18	
Minimum	2	3	14	
Maximum	1,741	5,770	1,384	
Random points (*n* = 166)				
Mean	223	1,301	307	
Median	152	882	268	Douglas fir
Standard deviation	221	1,286	223	
Standard error	17	100	17	
Minimum	3	5	1	
Maximum	1,297	6,171	860	

Note: all distances are given in meters

Table 8. Variables used in discriminant function analyses

Points analyzed	Landscape Scales: Site specific	Near analysis	Far analysis
All points (elk kill sites, live elk locations, AND random points)	Proximity to open road Vegetation-change	Lodgepole pine Non-road pixels	Open Douglas-fir Open road pixels
Paired groups (elk kill sites and live elk locations, live elk locations and random points)	Proximity to open road Vegetation-change	Open Douglas-fir	Open Douglas-fir Open road pixels

of elk kill sites were found in areas of intermediate vegetation loss (e.g., shelterwood and selection harvest treatments). Vegetation-change did not enter into either the near or far analysis DFA. This could be due to the slightly different method of measurement used in these databases. Site specific analysis identified the vegetation-change class found at each elk kill site, live elk location, and random point, while the *vegetation-change* variable used in the near and far analysis databases was a measure of the area occupied by each of the four vegetation-change classes within the sampling perimeter.

The near analysis database (containing a description of the landscape within a 200 m (656 ft.) radius of each elk kill site, live elk location, and random point) used 32 variables and provided an overall correct classification of 50%. The variable included during the first step was the number of pixels of the *lodgepole pine vegetation class* followed by the number of *non-road pixels*.

The far analysis database (containing a description of the landscape within a 700 m (2,297 ft.) radius of each elk kill site, live elk location, and random point) incorporated the same 32 variables used in the near analysis and provided an overall correct classification of 49%. The variable included in the far analysis DFA at step one was the number of pixels of the *open Douglas-fir vegetation class* followed by the number of pixels of *open road.*

To further investigate the importance of the specific vegetation classes used by the DFA, a use-availability comparison was made using a Chi-square test (Neu et al. 1974, Byers et al. 1984). Use was calculated as the relative percent of each vegetation class identified by a live elk location (site specific). Home range polygons were determined for both elk herds in the study

area with the adaptive kernel method (Worton 1989) using 112 independent live elk locations. Availability was calculated as the relative percent of each vegetation class contained within the home range of each elk herd. The results from each home range were first examined individually, and then combined and reported in Table 9. Elk use of the *Douglas-fir vegetation class* did not exceed the availability of the vegetation class, however, 20% of live elk locations used in the study were found in the *Douglas-fir vegetation class,* demonstrating the importance of these forests. Elk use of the *lodgepole pine vegetation class* significantly exceeded availability, while use of the *open Douglas-fir vegetation class* was not significantly different than its availability. Habitat use described by live elk locations was found to be different than the habitat use described by elk kill sites (Table 10). Habitat use described by live elk locations were also different than random points; however, no difference existed between elk kill sites and random points. A close examination of the variables used in the DFA was performed to help explain this finding. While live elk locations were found approximately 1 km (0.6 mile) farther from open roads than either elk kill sites or random points, the minimum and maximum distances from an open road are nearly identical. Further, all points used in this study (elk kill sites, live elk locations, and random points) were typically associated with areas that had sustained no vegetation-change within the past 10 years. The importance of these variables suggest a biological effect. Specifically, these results reveal a relatively uniform distribution of elk from open roads with increasing vulnerability close to open roads, and demonstrate selection by elk for sites without disturbance (Fig. 6).

A comparison of the mean patch size of *lodgepole pine vegetation class* polygons selected by elk ($\underline{x} = 77.65$ km^2, $n = 120$), with the mean patch size of all *lodgepole pine*

Table 9. Chi-square test of elk use during the hunting season and vegetation class availability

Vegetation class	Observed (use) Relative %	Expected (availability) Relative %	Chi-value
Cropland/ pasture	0.5	0.5	0.0
Foothills/ parklands	1.6	6.9	4.0
Disturbed grasslands	0.5	0.7	0.1
Other herbaceous	0.5	3.5	2.6
Sagebrush	1.1	5.4	3.5
Mixed grass/ shrub	0.5	0.7	0.1
Lodgepole pine	51.9	17.9	64.3
Ponderosa pine	7.0	5.3	0.5
Douglas fir	20.0	20.0	0.0
Mixed coniferous	9.7	20.2	5.5
Open Douglas-fir	4.3	9.9	3.1
Regenerating clearcut	1.6	2.1	0.1
		Chi-square	83.8
		Critical Chi-value (0.05)	19.7
		d.f.	11

Note: These results are the mean values for both elk herds.

Table 10. Summary of probability values from F-test of groups used in the discriminant function analysis

	Elk kill sites	Live elk locations
Live elk locations	0.00	n/a
Random points	0.32	0.00

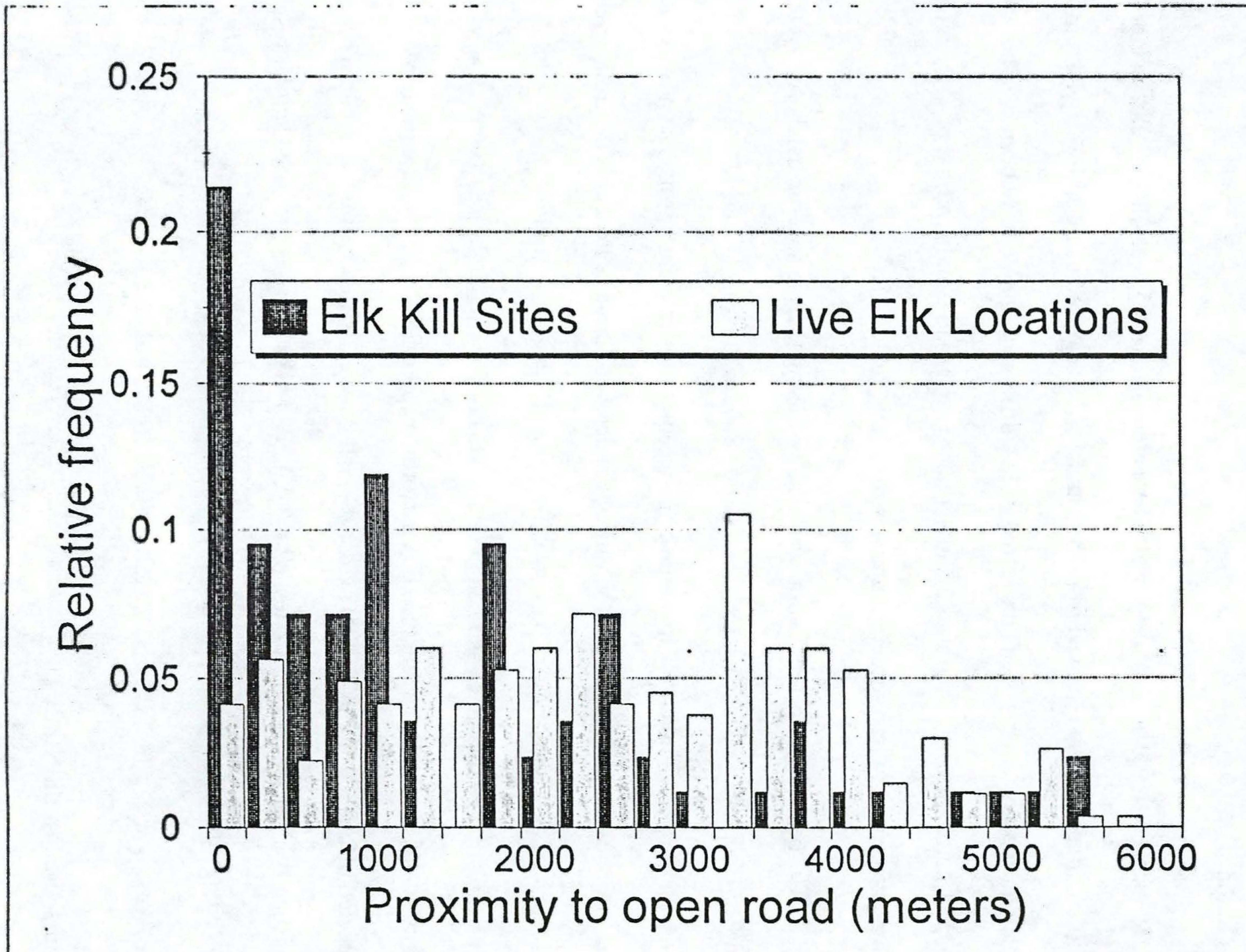

Figure 6. Proximity to open road distribution of elk kill sites and live elk locations

vegetation class polygons ($\underline{x} = 0.34$ km^2, $n = 415$), and with the mean patch size of all vegetation polygons ($\underline{x} = 0.16$ km^2, $n = 7{,}168$), was made using a Z-test. In all cases a significant difference was found ($P < 0.05$).

Subsets of the original databases where cow elk and 1.5 year-old bull elk, and/ or killed radio-collared elk were removed from the sample were analyzed using an F-test. For any of the exclusion subsets to have been considered valid a difference should have been seen between groups 1 and 2, or between groups 3 and 4, or between group 6 and groups 3 or 4. No significant difference between these subset groups was revealed (Table 11).

The best correct classification was achieved using the site specific database. At this scale, live elk locations were correctly classified 80% of the time (Table 12). The resulting eigenvalues reveal a relatively low ratio of between-groups to within-groups sums of squares. This indicates that the within-groups variance is nearly as large as the between-groups variance, and that a fair amount of overlap exists when comparing the descriptions of each group. This helps explain why overall classification rates were not very high (Norusis 1990). Kappa values (Titus et al. 1984) indicate that the DFA performed approximately 29% better than would be expected by chance alone (Table 12). Further, all three classifications were found to be statistically significant using a Z test ($P < 0.05$). Paired group tests produced similar results, but typically yielded higher correct classification rates (Table 13).

DISCUSSION

Points Used in the Study

Forty-nine percent of the bulls killed in the study area were 1.5 years-old. At this age bull

Table 11. Summary of probability values from F-test of exclusion database subsets

	Group 1	Group 2	Group 3	Group 4	Group 5
Group 2	0.34				
Group 3	0.00	0.00			
Group 4	0.00	0.00	0.24		
Group 5	0.31	0.46	0.00	0.00	
Group 6	0.00	0.00	0.38	0.38	0.00

Note: Group 1 (cow and spike bull elk kill sites) $n = 67$
Group 2 (adult bull elk kill sites) $n = 17$
Group 3 (cow and spike bull elk live locations) $n = 192$
Group 4 (adult bull elk live locations) $n = 75$
Group 5 (random points) $n = 166$
Group 6 (killed radio-collared elk locations) $n = 83$

Table 12. Results of discriminant function analysis

	% Correctly classified				
Database type	Elk kill sites	Live elk locations	Random points	Kappa	Z
Site specific	41	80	39	0.32	8.7
Near analysis	31	66	52	0.30	8.9
Far analysis	38	63	46	0.26	7.7
	$n = 84$	$n = 267$	$n = 166$		

Table 13. Results of paired discriminant function analysis

Database type	% Correctly classified: Elk kill sites	Live elk locations	Random points
Site specific analysis			
Elk kill sites and live elk locations	57	90	
Live elk locations and random points		82	55
Near analysis			
Elk kill sites and live elk locations	51	78	
Live elk locations and random points		78	54
Far analysis			
Elk kill sites and live elk locations	67	68	
Live elk locations and random points		65	75

elk have grown their first set of antlers (normally spikes), and are usually associated with cow groups (Geist 1982). Cow groups typically contain more animals than do the bachelor bull groups and may be easier for hunters to locate as they inevitably leave more tracks. For this reason, spike bulls may be more vulnerable to hunting. Another potential reason why spike bulls may seem more vulnerable to hunting is that this cohort contains the largest number of individuals and correspondingly, accounts for the largest proportion of kill sites. In comparison, the age of cows killed in the study area was relatively uniform. The mean age of elk killed (and aged) in the study area was approximately 2 years for bulls, and approximately 3 years for cows. This deviation may reflect a real difference in the age structure of the elk population or disproportionate vulnerability between 1.5 year-old bulls and mature bulls. Another factor affecting the reported age distribution of killed elk was the number of cows that were brought to the game check station in quarters ($n = 31$ (28%)). In speculation, it seems likely that at least some of these cows were older, larger animals, and because of their size, were more manageable by the hunter in quarters than in 1 piece. Similarly, smaller, younger animals were more likely to be brought to the game check station in 1 piece. As a result, younger cows may have had a greater probability of being aged than older cows. Based on the relatively small proportion of unaged cows it seems unlikely that the mean age of killed cow elk would change much even if all the unaged cows were older animals (> 4.5 yrs).

As noted earlier, the number of bull elk killed during the first week of the hunting seasons was approximately equal to the total number of bulls killed during the remaining four weeks. Decreased hunting pressure after the first week of the season may offer a partial explanation for this observation, however another important factor was that fewer bulls were left alive after the

first week of the hunting season.

Biological Interpretations

Elk kill sites could not be differentiated from random points with the variables used in this study. This does not imply that elk or hunters use the landscape randomly, rather it reflects the random occurrence of a specific sequence of events, such as a hunter and an elk in close proximity of each other, and the hunter detecting and shooting the elk without the elk first detecting the hunter and escaping.

Live elk locations were found approximately 1,000 m (3,281 ft.) further from open roads than random points or elk kill sites. Other road variables were included in both the near and far analysis (e.g., the number of *non-road*, and *open road* pixels, respectively). This illustrates a discernible benefit of walk-in areas and the increased vulnerability of elk in areas where roads remain open during the hunting season. Numerous other studies have reported similar results concerning the influence of roads on elk habitat effectiveness (Lyon and Christensen 1992) and use (Marcum 1975, Perry and Overly 1976, Rost and Bailey 1979, Lyon and Ward 1982, Skovlin 1982, Irwin and Peek 1983, Daneke 1980, Edge 1985, Lyon et al. 1985), and elk vulnerability (Lyon and Canfield 1991). The influence of roads and tree canopy on habitat effectiveness was studied by Lyon (1979 and 1983), who found that as road density increased, habitat effectiveness for elk decreased, and that this effect can be offset to some degree by maintaining forested cover adjacent to the road. Basile and Lonner (1979) reported that while unrestricted road travel was detrimental to elk security, vehicle restrictions on existing roads seemed to increase hunter effort. Hunters using walk-in areas will undoubtedly exert more effort, but they will not cover as much

area, and may not be able to access sites farthest from the trailhead. In the Clearwater Drainage of Idaho, Unsworth and Kuck (1991) and Unsworth et al. (1993) studied bull elk vulnerability and habitat use by comparing mortality in roaded and unroaded portions of their study area. Annual survival rates of bull elk in roaded areas were significantly lower than in unroaded areas.

Live elk locations used in this study were associated with areas having no vegetation-change in the past 10 years. Although, elk kill sites were also associated with areas of no vegetation-change, 35% of elk kill sites were found in areas of intermediate vegetation loss (e.g., shelterwood and selection harvest treatments). Live elk appeared to spend relatively little time (4%) in areas with intermediate vegetation loss. This suggests that elk vulnerability increased where a timber harvest treatment had occurred.

The *open Douglas-fir vegetation class* was not selected by elk in the study area during hunting season. Only 5% of live elk locations were found in the *open Douglas-fir vegetation class* compared to nearly 17% of elk kill sites. This indicates that elk vulnerability increased in the *open Douglas-fir vegetation class* which is characterized by minimal canopy cover (< 31%) and a lack of hiding cover. This agrees with the results of other researchers (Irwin and Peek 1983, Wright 1983, Canfield 1988, and Hurley and Sargeant 1991), who found that elk use of open areas decreased during the hunting season. Elk that ventured into poor security areas, such as the *open Douglas-fir vegetation class* and timber harvest areas, had an increased probability of being killed. Further, Vales (1996) reported that elk vulnerability increases as security cover decreases.

Elk use of the *lodgepole pine vegetation class* significantly exceeded availability. All

other vegetation classes showed use to be approximately equal to availability. A characteristic of the study area is that the most popular trailheads are located at low elevations (approximately 1,128 m (3,700 ft.)). From these points, elevation increases as one enters the walk-in area. *Lodgepole pine vegetation class* polygons are found at relatively high elevations (approximately 1,524 m (5,000 ft.) or more) and consequently, are not in close proximity to many trailheads. A potential explanation for elk selection of the *lodgepole pine vegetation class* may be that this variable is correlated with the *proximity to open road* variable used in site specific analysis, and that elk are simply selecting sites that are farthest from human activity (Marcum 1975, Lyon and Ward 1982, Skovlin 1982, and Edge 1985). A correlation test was performed using *proximity to open road* measurements on the X-axis, and the number of pixels of the *lodgepole pine vegetation class* occurring within a 200 m (656 ft.) radius of each elk kill site and live elk location, on the Y-axis. The results of this test indicated that only 15% of the variation in the *lodgepole pine vegetation class* variable was explained by the *proximity to open road* variable ($r = 0.39$, $n = 243$). Therefore, elk use of the *lodgepole pine vegetation class* was not an expression of *proximity to open road.*

Several studies have indicated that patch size may be important to elk security (Lyon and Canfield 1991, Hillis et al. 1991). The mean patch size of the *lodgepole pine vegetation class* polygons selected by elk is much larger than the mean patch size of the available polygons. This is because the majority of live elk locations were found in the largest available polygon on the landscape, indicating selection for large patch sizes during the hunting season. Selection for large patch size has been previously reported by Lyon and Canfield (1991). They found the

smallest patch associated with an elk location increased from 0.38 km^2 (0.14 mi^2) before hunting season, to 0.63 km^2 (0.24 mi^2) after the onset of the hunting season.

Hiding cover was determined for each ground-truth sample by estimating how often an elk could be seen at a distance of 61 m (200 ft.). Three discrete classes were used; a value of 1 indicated that elk would be seen all the time, 2 indicated that an elk would be seen part of the time, and 3 indicated that an elk would never be seen (cf. Skovlin 1982). The *lodgepole pine vegetation class* had the highest hiding cover estimate and potentially the highest canopy cover. The *open Douglas-fir vegetation class* had a comparatively low hiding cover estimate and a canopy cover of

< 31%. This may be one of the simplest and most plausible reasons that elk selected the *lodgepole pine vegetation class.* Other studies have arrived at similar conclusions and found that elk select sites with high canopy closure and/ or dense cover (Marcum 1975, Edge et al. 1988, Hillis et al. 1991). Irwin and Peek (1983) found that elk preferred pole-timber sites with > 75% canopy closure and that there was little use of clearcuts, grass-shrub, or brushfield sites. Hurley (1994), and Hurley and Sargeant (1991) reported that elk in roaded or partially roaded areas increased their use of dense coniferous cover and subsequently decreased their use of more open sites during the hunting season.

Lyon (pers. comm.) noted that use of both the *lodgepole pine* and *open Douglas-fir vegetation classes* by hunters in Chamberlain Creek was equal to availability. A direct relationship between elk use and hunter density was not evident, however many of my data, results, and observations indicate that elk were indirectly responding to hunting pressure by

selecting sites that reduced their vulnerability (e.g., sites farther from open roads with densely forested cover in large patches).

Elk selection for the *lodgepole pine vegetation class* could have been forage based. I collected no data concerning forage availability or use within the vegetation classes, however, Edge et al. (1988) reported that late summer elk habitat use in Chamberlain Creek shifted to more closed canopy sites, probably in response to decreased palatability of forage on more open sites. Vegetation growing in shaded areas remains in a more nutritious state than that grown in open areas (Hanley et al. 1989). After freezing temperatures have killed the succulent vegetation (usually by mid to late September (Marcum, pers. comm.)) elk satisfy their energy requirements by relying on the cured forage found in open areas (Marcum 1975).

The *lodgepole pine vegetation class* may provide a security area for elk. This alternative seems more feasible than selection for forage because there is relatively little forage in lodgepole pine forests. However, Marcum (1975) found bear grass (*Xerophyllum tenax*) constituted 24% of the rumen volume of hunter killed elk in the Sapphire Mountains of western Montana. Bear grass was commonly found in the understory of the *lodgepole pine vegetation class* in the study area. Still, elk used the largest polygon on the landscape and selected sites with the highest available hiding cover and canopy cover. These characteristics describe the *lodgepole pine vegetation class*.

Several studies have identified clearcuts as having a detrimental impact on elk use of the landscape. In Chamberlain Creek, elk use of clearcuts during hunting season was minimal. In my study, only 1 live elk location was found in a clearcut polygon during three hunting seasons.

Similarly, only 5 elk kill sites were found in clearcut polygons. These observations tend to support the research of Marcum (1976), Lyon (1976), Lyon and Jensen (1980), and Edge and Marcum (1985). In each of these studies, elk activity was directed away from the disturbance of logging. Other studies have demonstrated that elk use of clearcuts was less than expected (Marcum 1975, and Marcum et. al 1984). The degree to which elk avoided or otherwise failed to use clearcuts was influenced by cover considerations, and proximity to open roads.

Selection by elk for north aspects was reported by Irwin and Peek (1983). Another study that found aspect to be important in elk use of the landscape was Marcum et al. (1984). My study failed to identify aspect as an important variable. However, the goal of this study was to identify landscape elements that influence elk security and not necessarily those that best describe elk use of the landscape. This fundamental difference in study objective may explain why aspect was not detected by DFA. Another potential explanation concerns the method used to determine aspect. In my study, modal aspect for each vegetation polygon was used to describe the aspect at each point (elk kill site, live elk location, and random point). The fact that this variable represents a generalization for all the 30 m (98.4 ft.) pixels in an entire polygon may help explain why aspect was not detected by DFA.

The effect of snow depth was not included in my analysis of elk mortality because the objective of my study was to identify landscape characteristics that land managers can control, alter, or manipulate to improve elk security. However, the effect of snow depth on elk movement and its potential influence on elk vulnerability is not challenged by the results of this study (cf. Youmans 1991). To address the effect of snow on elk vulnerability, I recorded the estimated

snow depth at each elk kill site, and examined the distribution of elk kill sites relative to snow depth. I found an inverse relationship between the frequency of elk kills and snow depth. However, a direct inference is not appropriate in this case. The majority of elk kills occurred during the first week of hunting season which coincides with the period of least snow depth. Further, snow cover during 1993, 1994, and 1995 hunting seasons was relatively uniform among these years, and so the influence of snow cover on elk vulnerability could be not determined.

I believe that elk selected the *lodgepole pine vegetation class* to increase their security. The *lodgepole pine vegetation class* achieved increased security not by being composed primarily of lodgepole pine, but by having substantial hiding cover, canopy cover, and large patch size. Of interest, is that of the 415 individual polygons assigned the *lodgepole pine vegetation classification*, elk in the study area routinely selected the same 10 polygons, with 85% of those locations occurring in the same polygon. This polygon, as alluded to earlier, was the largest available polygon on the landscape. In light of this, two points must be kept in mind. First, if the locations were randomly distributed, large polygons should contain more point locations than smaller polygons. Therefore, this alone would not indicate selection for large patches. However, when coupled with the data that I have presented regarding patch size comparisons, use-availability tests, and the results of DFA, selection for large patches becomes more credible. Second, elk probably cannot detect polygon boundaries between most forested vegetation classes. Thus, the vegetation classification becomes less important than the characteristics used to describe them. The results of this study demonstrate that elk selected particular elements of the landscape during the hunting season. These sites or areas:

1) were not in close proximity to open roads,

2) had a low road density , and

3) contained forested cover in large patches, which:

    a) had no significant change in vegetation within the past 10 years, and

    b) provided substantial hiding cover.

Based on the results of this study and associated field observations, elk responded to hunting season pressure in one of two ways. The first was to seek large areas of forested cover with dense canopy closure and substantial hiding cover which are far from open roads. While these elk selected particular elements of a landscape that subsequently reduced their vulnerability to hunting, no site existed which could eliminate vulnerability. The second response was to seek property closed to hunting by the general public (Wright 1983, Hurley and Sargeant 1991). My study focused on detecting and explaining the variables important to elk security on land open to the general public. However, elk use of private ranches that are closed to the general public cannot be ignored. In 1993 and 1994 several large ranches in the study area were open to limited hunting for elk on their property. As a result, only 21% of live elk locations were found on these ranches in 1993, and only 18% in 1994. In 1995, hunting was not allowed on numerous ranches in the study area. The elk responded to this refuge effect, and as a result, 44% of live elk locations were found on these properties. Apparently, elk responded to the escapement provided by these ranches even though large forested security areas were not located on the ranch lands. These elk survived in areas that were near open roads, contained minimal hiding cover, but offered high quality forage (e.g., alfalfa) and security. A problem associated with this scenario is that elk are much more vulnerable to hunting while on the ranch because no large areas of

forested cover exist, and elk may have become habituated to ranch activities and the presence of people. When disturbed, elk left the private ranches and sought security areas in high elevation forests. In the process of traveling from low elevation private ranches to high elevation forests, elk passed through sparsely forested foothills where hunter density and elk vulnerability was highest.

Assessment of Error and Bias

Hunters who killed an elk may have been reluctant to participate in the study and disclose the actual location of the kill site. While hunters were not obligated to participate in the study, the overwhelming majority were very cooperative (99%). Even with their cooperation however, less than half of all reported elk kill sites were located in the field. This was primarily due to weather conditions, and/ or errors in map interpretation.

Elk kill sites that were most likely to be found and included in the DFA were those that were relatively easy to locate (i.e., close to roads, trailheads, and in open areas). This bias may have affected my study by decreasing the mean proximity to open roads for elk kill sites. However, the maximum distance from an open road was nearly identical for both elk kill sites (5.6 km (3.5 miles)) and live elk locations (5.7 km (3.6 miles)). This suggests that because of the heavily-roaded condition of the study area, elk cannot find areas that are more than 6 km (3.7 miles) from an open road. Based on this potential, the actual error caused by this bias may have been minimal. Further, I examined all elk kill site reports that were not located in the field, and plotted each using the point identified by the hunter (n = 69). Using PC ARC/INFO (NEAR) I determined the proximity of each point to an open road (x = 1,280 m (4,200 ft.)), and to any road

(x = 250 m (820 ft.)). Using PC ARC/INFO (IDENTITY) I determined the Douglas-fir vegetation class was most often found at these points. These results are nearly identical to those reported for the elk kill sites used in my analysis (Fig. 7).

Hunters seeking trophy animals may pass-up an elk that could have been killed, resulting in elk kill sites that reflect selection by hunters instead of poor security decisions by elk. To address this possible bias, 55 hunters who had killed an elk in 1995 were asked whether they had passed-up any elk that could have been legally harvested. Ninety-three percent indicated they shot the first legal elk they saw. Based on this finding, I assumed that this potential bias was negligible.

Several new roads were constructed during the study that were not included on the GIS coverage, resulting in measures of proximity that exceed the real distance. This error affects proximity measurements for <u>all</u> point locations (elk kill sites, live elk locations, and random points) and is therefore relatively inconsequential because no bias was established.

The vegetation classes used in this study were the result of a supervised classification based on a set of 242 ground-truth data. While many polygons were correctly classified, some were incorrectly classified, and others were correct only as a gross generalization (e.g., a polygon labeled lodgepole pine might consist primarily of lodgepole pine but may also contain a considerable percentage of Douglas-fir). In addition, structural heterogeneity existed within the vegetation classes. However, because this error affects all groups (elk kill sites, live elk locations, and random points) equally, no bias was established.

No significant covariates or correlates were found in the databases. Data used in the DFA

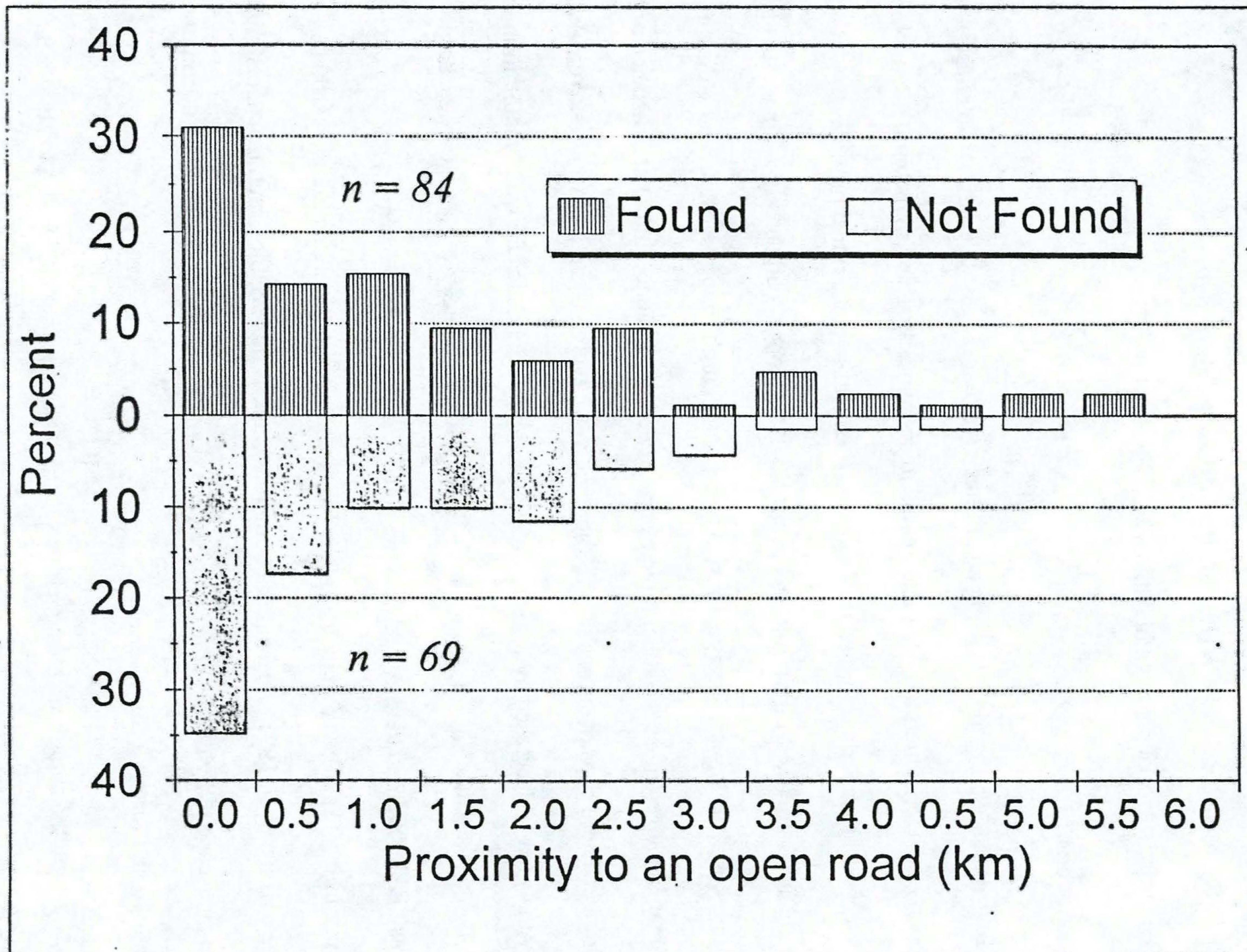

Figure 7. Proximity to open road distribution of elk kill sites that were found versus those that were not found.

were not normally distributed even after a log transformation was performed. However, violation of this assumption is typical of wildlife studies (Green 1974, and Edge et al. 1987) and, due to the robustness of DFA (Klecka 1975), these results should be viewed as confirmatory and not exploratory or descriptive in nature (Morrison et al. 1992).

Management Implications

Implementing the following conditions in timber harvest planning, road construction, and property development (etc.) has the potential to dramatically decrease the vulnerability of elk in a given area; 1) properly designed road closures (i.e., walk-in areas) that provide elk with areas that are at least 1 km (0.62 mile) from an open road, 2) zero open road density and a relatively low closed road density, and 3) large forested patches with high canopy closure, and hiding cover estimates that provide elk with complete or nearly complete concealment at a distance of 61 m (200 ft.). These considerations must be applied collectively to be effective as elk vulnerability is only marginally decreased by forested cover with high canopy closure while maintaining an unrestricted use of roads (cf. Lyon 1979). It does not seem feasible to assign threshhold values to act as maximum road density or minimum patch size guidelines. However, my data suggests that the minimum patch size required by elk is larger than previously recommended (100 ha (250 acres), Hillis, et al. 1991). Because of numerous interacting variables, land managers must assess each landscape individually, considering hunter density and hunter use patterns in conjunction with road and forested cover variables.

Elk in the study area presumably used the landscape in ways similar to elk in other regions, states, or provinces. The results of this study agree with numerous other research

projects regarding elk security and vulnerability. I found that open roads were detrimental to elk security, which confirms previous research by Unsworth and Kuck (1991). Further, elk security increased in large forested patches that contained substantial hiding cover, and had dense canopy closure. These same results were reported by Hurley and Sargeant (1991). Accordingly, the conclusions arrived at by this study should be applicable to other elk herds.

SUMMARY OF RESULTS

Elk kill sites could not be reliably differentiated from random points. Live elk locations were correctly differentiated from elk kill sites and random points using two variables in each of three analyses (site specific, near, and far). Landscape elements selected by elk:

1) were not in close proximity to open roads,
2) had a low road density , and
3) contained forested cover in large patches, which:
    a) had no significant change in vegetative cover within the past 10 years, and
    b) provided substantial hiding cover.

Live elk locations were found an average of 1,000 m (3,281 ft.) farther from open roads than elk kill sites. Only 17% of live elk locations and 45% of elk kill sites were found within 1,000 m (3,281 ft.) of an open road. Elk may have been using these areas for forage (especially when snow had covered the vegetation at higher elevations), or may have been traveling from lower elevation private ranches to higher elevation security areas due to some disturbance encountered on the private ranch.

Elk locations were found in areas with no vegetation-change. However, 4% of live elk locations and 35% of elk kill sites were found in areas where shelterwood or selection harvest treatments had occurred. Elk vulnerability increased in areas that had sustained vegetation losses by any of the various timber harvest methods (e.g., shelterwood, selection, seed tree, or clearcut treatments).

While only 5% of live elk locations were found in the *open Douglas-fir vegetation class* (which is characterized by < 31% canopy cover, and a lack of hiding cover), 17% of elk kill sites occurred there. In contrast, 52% of live elk locations occurred in the *lodgepole pine vegetation class* (characterized by dense canopy closure and substantial hiding cover) and only 8% of elk kill sites. Elk use of the *open Douglas-fir vegetation class* was equal to availability, however elk vulnerability increased in and near these areas.

The summary of landscape elements selected by live elk does not describe security areas that are independent of other influences. With sufficient hunting pressure any elk is vulnerable in any type of cover (Lyon and Canfield 1991). Further, elk security is dynamic and based ultimately on moment-to-moment decisions and reactions by the animal. Security areas must meet not only cover and topographic requirements, they must also be large enough to ameliorate the effect of concentrated hunting pressure.

Hunter density was not detected by DFA but will become more important in the future as hunter numbers increase (Flather and Cordell 1995) and/ or elk security areas are further depleted. Additional research needs to be conducted to better understand the role of increasing hunter densities on elk security (Vaske et al. 1995, Knight and Cole 1995).

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Chapter 8

ELK USE OF PRIVATE LAND REFUGES

ELK USE OF PRIVATE LAND REFUGES

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***Abstract*:** Elk (*Cervus elaphus*) distributions and populations have expanded as habitat management and effective hunting season regulations have reduced vulnerability to hunting. In addition, elk find security during hunting seasons by using private lands closed to hunters. Incidental to studying long-term responses of elk to habitat modification, we documented the use of private lands as refuge areas by radio-collared elk. The use of private land refuges by 2 western Montana elk herds was first observed during the hunting season by a small number of elk. The proportion of each elk herd using these refuges and the duration of use has increased. Limited hunting of elk within 1 of these refuge areas reduced both the proportion of the elk herd using the area and the time spent there. Even in areas with dense cover far from open roads that provides good security habitat for elk during the hunting season, elk use of private land refuges is likely to occur if these areas are available within or adjacent to elk herd ranges. The availability of these private land refuges will pose increasing challenges to wildlife and land managers.

Key Words: *Cervus elaphus*, elk, habitat, hunting, Montana, private land, refuge

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Since the turn of the century, elk distributions and densities have increased markedly in response to regulated hunting seasons and habitat management. As a result, elk occupy nearly all suitable habitat available under current land use constraints, and densities in many areas are at or near all time highs. Elk security during the hunting season, mostly to protect the bull segment of elk populations, has replaced optimum habitat configuration for maximum elk use (Thomas et al. 1979) as the primary goal of many managers (Hillis et al. 1991). In addition, elk avoid hunter pressure during the hunting season by finding forms of security other than habitats isolated from open roads with dense cover; elk may use private lands that are closed to hunting as an alternative form of security (Edge et al. 1984). However, the factors that result in the use of these alternative forms of security are poorly understood. Incidental to the original Chamberlain Creek Elk Study (Marcum et al. 1984), Edge et al. (1984) documented the use of private lands by a hunted elk herd. The use of private land by elk in the study area was thought to be temporary when first observed, but has continued through this research project, >10 years later. Analyses and interpretation of results related to the main objectives of this study were made more complex by increasing proportions of the 2 elk herds using areas outside the managed forest lands of the study area. This use of private lands is a trend common throughout the west, and poses a new set of questions to wildlife and land managers. In this paper we document the use of 2 private land refuges by the 2 elk herds using the Chamberlain Creek study area.

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STUDY AREA

The study area lies in the northern Garnet Mountains of western Montana, 56 km east of Missoula (Fig. 1). Approximately 80% of the area is forested, and these areas fall within the Douglas fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*) climax series of the Montana Forest Habitat Types (Pfister et al. 1977). Pastures and hayfields, natural meadows, and clearcuts account for most of the rest of the area. Elevations range from 1,160 to 2,090 m. Montana Highway 200 delineates the northern boundary of the study area. Timber management is the primary use of the forested public and private lands, and much of the study area has been extensively logged within the last 60 years. Portions of the area are grazed by cattle and horses.

Big game hunting in the fall is the main recreational activity. Most of the study area falls within the cooperative Blackfoot Special Management Area (BSMA), implemented in 1974, which allows walk-in hunting on BLM, Plum Creek, Lubrecht Experimental Forest, Montana Department of State Lands, and portions of several private ranches. Hunting was not allowed on certain areas of private ranches, designated as "safety zones," that protected irrigation systems, livestock, and areas of human habitation. The study area falls within Montana Big Game Hunting District 292. The hunting season for elk in the area consists of a 5-week archery-only season, open to either sex elk from early September to mid-October and a 5-week general rifle season ending the Sunday after Thanksgiving Day. Antlered bull elk may be harvested by licensed hunters, while antlerless elk can only be harvested with a special permit. The number of special permits offered were 50 during the first study period and 150-250 through the second study.

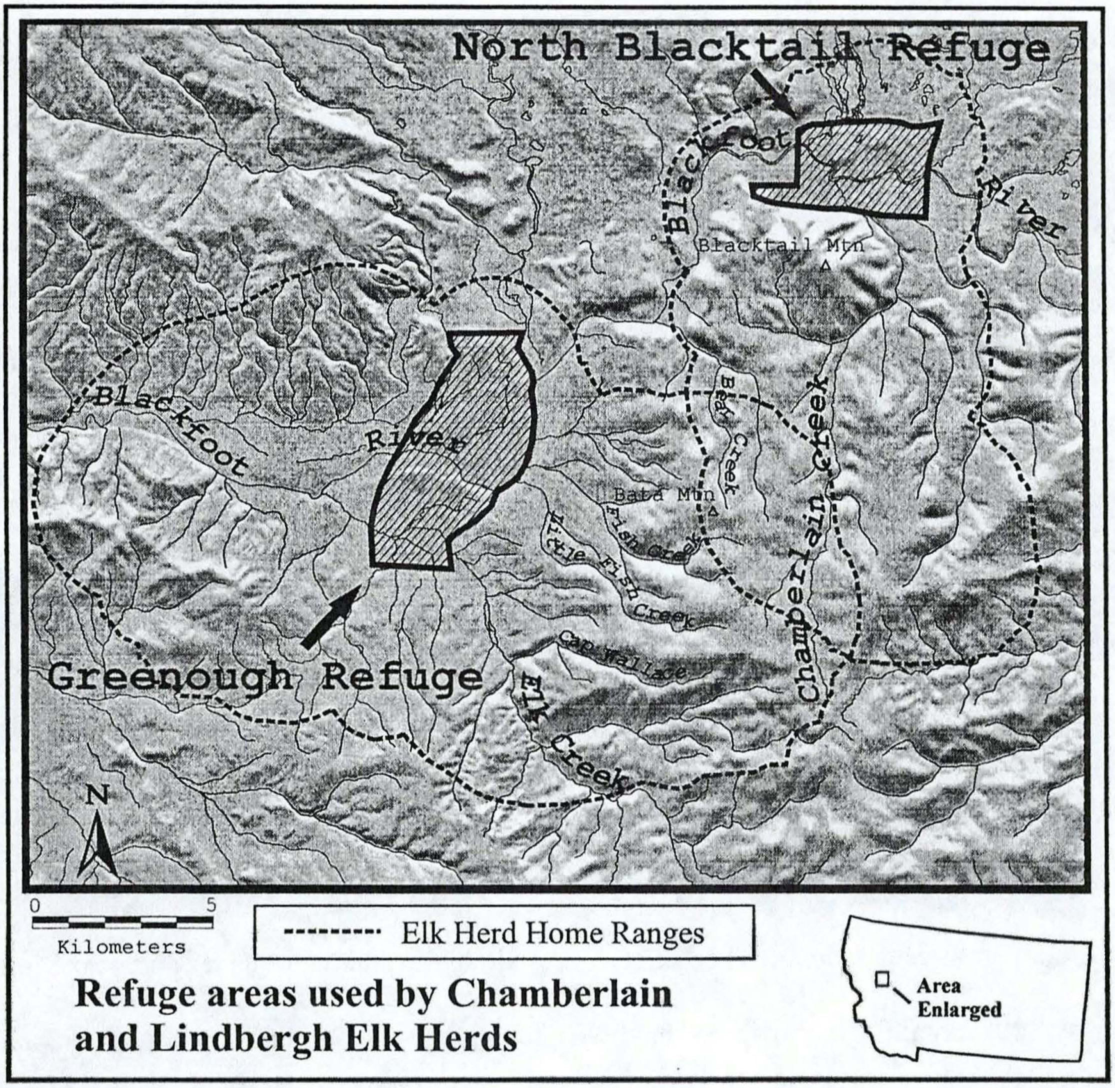

Figure 1. Study area showing the cumulative seasonal home ranges of the Chamberlain and Lindbergh elk herds and the refuge areas used by each herd.

There are both private and public lands in the study area. Generally, the BLM owns forested lands at the highest elevations, Plum Creek Timberlands L.P. owns forested lands at mid elevations, while private ranches bound the study area to the north and west at the lowest elevations. These private ranches consist of irrigated hay fields and big sagebrush (*Artemesia tridentata*) bunchgrass cover types, as well as some forested timberlands. State-owned lands, including part of the University of Montana's Lubrecht Experimental Forest are also located in the study area.

Two areas of private land in particular were used by the Chamberlain and Lindbergh elk herds. The Lindbergh elk herd uses a portion of a large ranch that will be referred to as the Greenough Refuge (GR). This ranch of approximately 3,238 ha (8,000 acres) has changed ownership twice since the original study. The entire ranch was closed to public and private hunting until 1974 when portions of the ranch were opened to public hunting as part of the BSMA cooperative agreement. The "safety zone" along the Blackfoot River and near Montana Highway 200, containing the irrigated hayfields, remained closed to hunting until the ranch was sold in 1986. Under the new ownership from 1986-92, these hayfields received light hunting pressure by the owners, friends of the owners, and ranch hands. This hunting pressure persisted until 1993 when Montana Department of Fish, Wildlife, and Parks (MDFWP) initiated an early season antlerless elk hunt, permitting 5 hunters/week from 30 August through 31 October. In 1994 this hunt was modified to allow 5 hunters/week from 17 October through 27 November, mostly coinciding with the general hunting season. These hunts were discontinued in 1995 and limited hunting by ranch hands continued.

The Chamberlain elk herd used lands on 2 adjacent ranches, which will be referred to as

the North Blacktail Refuge (NBR). The east portion of the NBR belongs to a ranch of 2,630 ha (6,500 acres) and the west portion belongs to a ranch of approximately 809 ha (2,000 acres). The NBR consists of mostly big sagebrush grasslands and limited forest, much of it near State Highway 200. The eastern ranch contains an irrigated hayfield along the Blackfoot River. Both ranches have a history of very limited elk hunting. The eastern ranch has been lightly hunted by owners and close friends, while the western portion was un-hunted until 1986 when the new owners occasionally bow hunted for elk during the archery season. The area of highest elk concentration is within a relatively small portion of the western ranch, within 600 m of MontanaHighway 200.

METHODS

Elk from 2 discreet elk herds (Edge et al. 1986) were monitored during 2 separate time periods: 1977-1983 and 1993-1996. During the first study, elk were captured in corral traps while during the second study, Clover traps (Clover 1954, Thompson et al. 1989) and a net-gun fired from a helicopter were used. Corral traps were placed on the southern and eastern edges of the GR to capture Lindbergh elk during the first study. For the second study, elk were captured primarily within the GR with the helicopter and net gun. Several elk were captured during the second study period using Clover traps set within the higher elevation, forested portion of the study area. These traps were within the Lindbergh herd home range, approximately 6 km east of the GR. During the first study, elk from the Chamberlain herd were captured using a corral trap set at the southern base of Blacktail Mountain, within the forested portion of the study area, and approximately 4 km south of the NBR. Most elk during the second study were captured in the

vicinity of the old corral trap using a helicopter and net gun, while others were captured in Clover traps higher in the Chamberlain Creek drainage and further from the NBR. Cow elk were fitted with either polyvinyl chloride (PVC) or acrylonitrile butadiene styrene (ABS) plastic pipe collars containing 150-152 MHz radio transmitters .

Radio-collared elk were located once weekly from mid-May through mid-October and twice weekly through the general hunting season, with a Piper Super Cub or Cessna 182 (first study) and a Citabria (second study). Locations were plotted on 7.5 minute USGS topographic maps and UTM coordinates were determined from these plotted locations. All elk seen from the air at radio-collared elk locations were counted. Results from yearly elk population trend count flights were obtained from the MDFWP.

Private land refuge areas were delineated on a Geographic Information System. Counts of elk locations within these refuge areas were separated by season into: parturition (15 May - 15 June), summer (16 June -31 August), rut (1 September-start of general elk hunting season), hunting season (5 weeks, ending the Sunday after Thanksgiving day).

RESULTS

During the first study we obtained 2,606 radio locations from 66 female elk between mid-May and early December, 1977 through 1983; and 1,627 locations from 39 female elk between Fumid-May and early December, 1993 through 1996 for the second study (Appendix A). Elk trend counts by MDFWP (1997) suggest increasing elk numbers through the first study and continuing to approximately 1993, and declining afterwards (Fig. 2).

The first documented use of the GR by the Lindbergh elk herd occurred in 1980 when

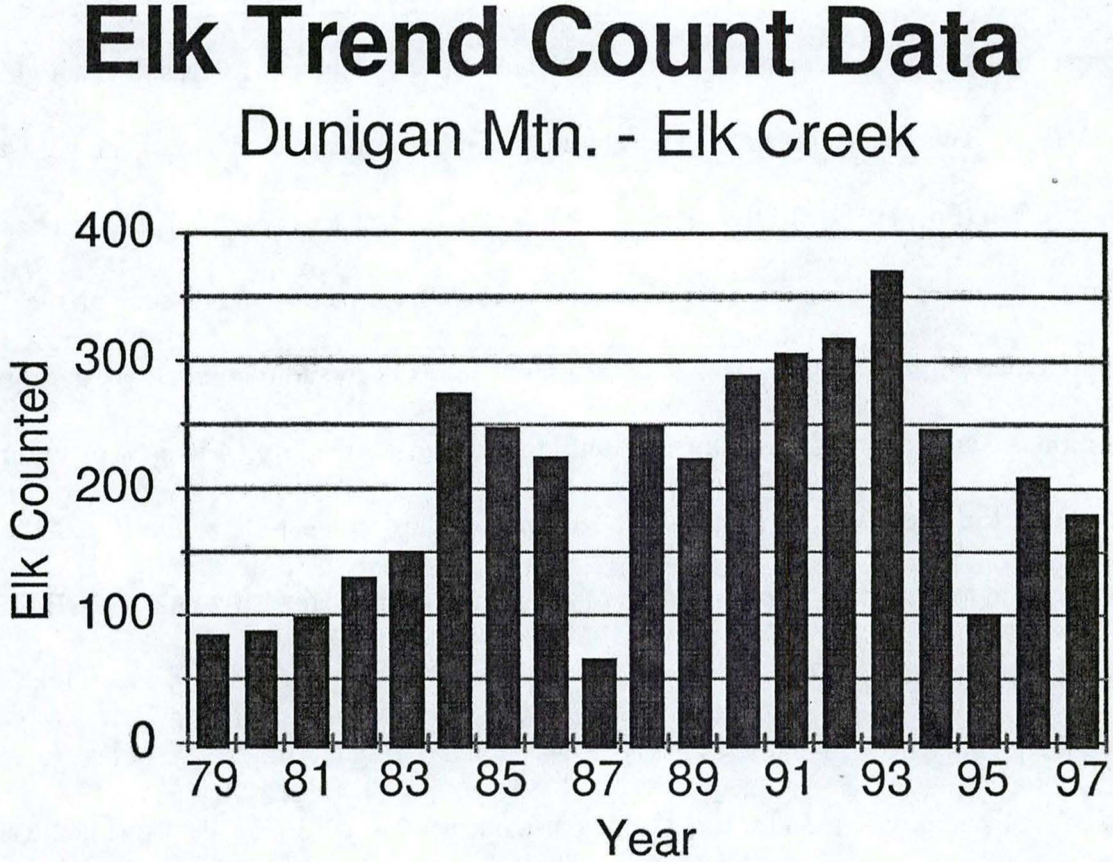

Figure 2. Annual elk population trend counts for the Deer Lodge Unit - Dunigan Mountain to Elk Creek, 1979-1997 (Montana Department of Fish, Wildlife, and Parks 1997).

6% of the hunting season locations (1 of 9 radio-collared elk) were within the area closed to hunting (Fig. 3). The percentage of hunting season locations in the GR increased to a high of 75% in 1993. This use of private land was by 11% of radio-collared elk in 1980 and grew to 100% by 1996 (Fig. 4). Use of the same area during the rut was first noted in 1982 and has continued during each year since then. As many as 114 elk were counted at 1 time on the GR during telemetry flights at this season (Fig. 5). Use of the GR by radio-collared elk during parturition or summer was not documented until the second study. From 4 to 64% of summer locations for Lindbergh elk were on the GR each year of the second study, while 12 to 51% of calving season locations for the last 3 years of the second study were also within the GR (Fig. 2).

Elk use of the NBR by Chamberlain elk herd was less pronounced than use of the GR by the Lindbergh elk herd. Some use of the NBR was noted during the first study, but represented <20% of rut or hunting season locations and no use occurred in 1983 (Fig. 2). During the second study, however, elk use of the NBR increased considerably; up to 37% of hunting season locations and 26% of rut locations for the Chamberlain herd within the NBR. Up to 75% of radio-collared elk of the Chamberlain herd have used the NBR at one time. Summer use of the NBR was documented in 1996 and reports indicate even heavier elk use during summer 1997. Elk counts on the NBR have been as high as 81 during the rut and 72 during the general hunting season (Table 1). Tabular data for elk use of refuge are presented in Appendix E.

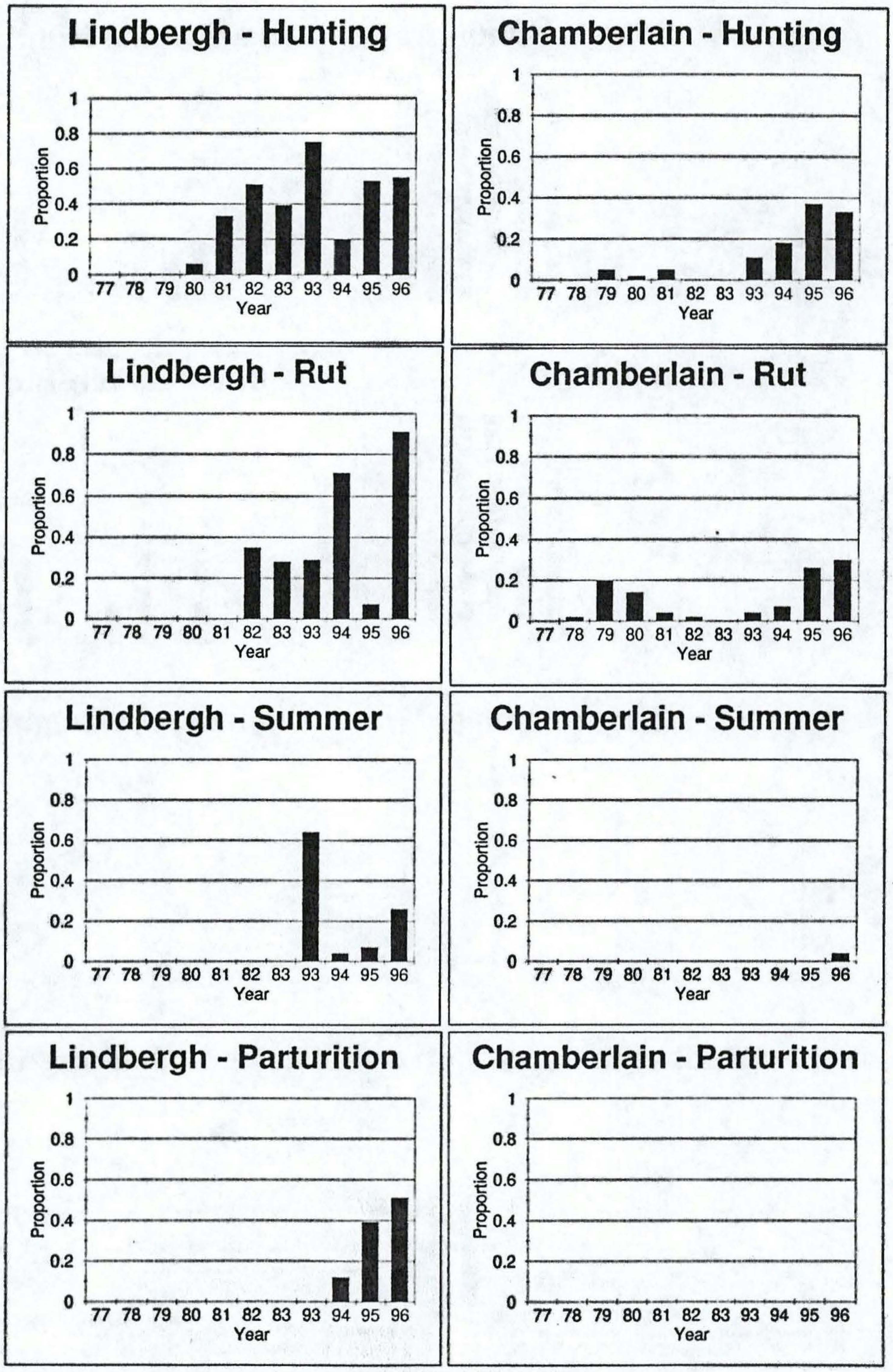

Figure 3. Percent of cow elk locations within private land refuge, by season, for the Chamberlain and Lindbergh elk herds.

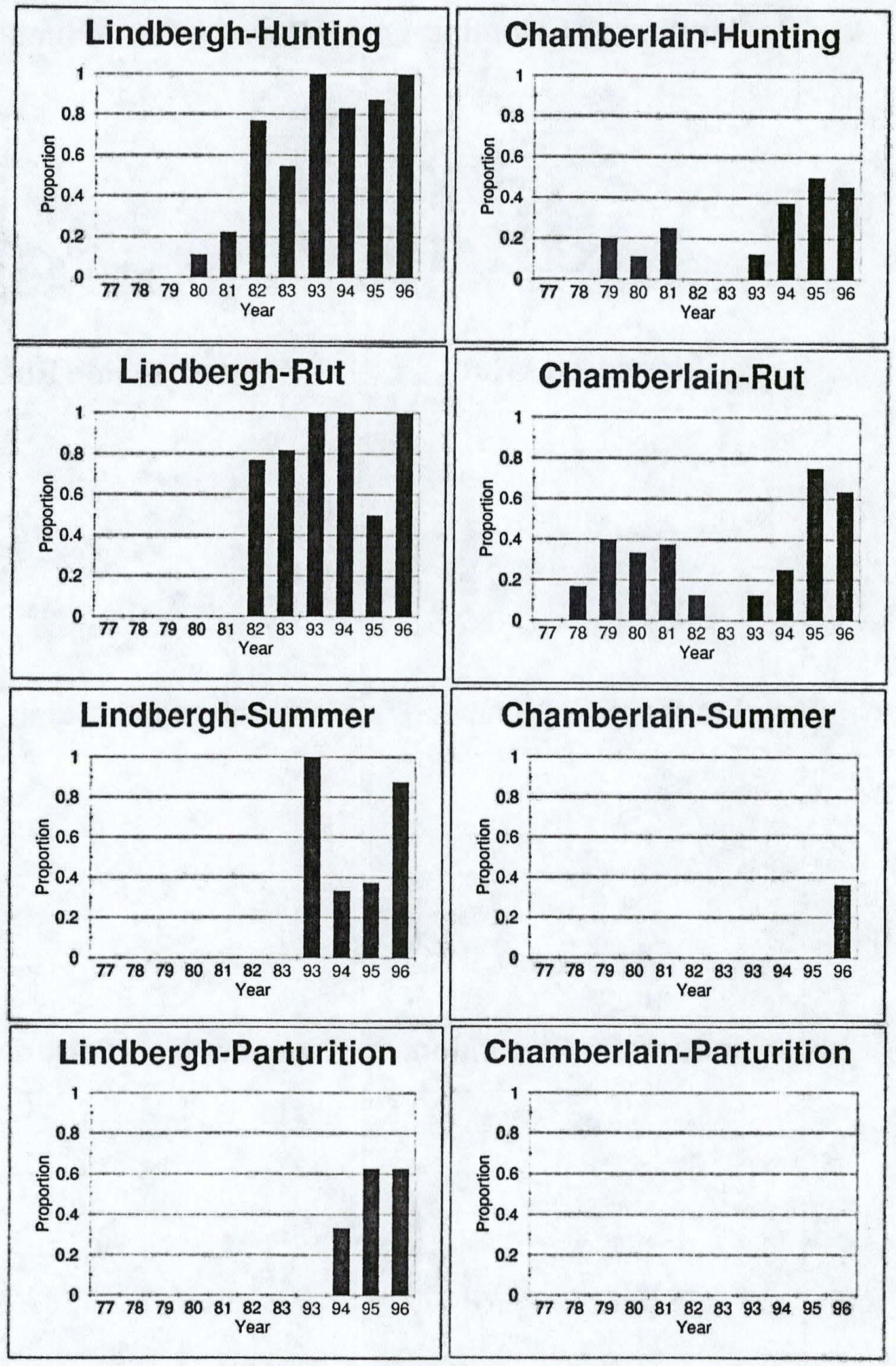

Figure 4. Percent of radio-collared cow elk that occured within private land refuge, by season, for the Chamberlain and Lindbergh elk herds.

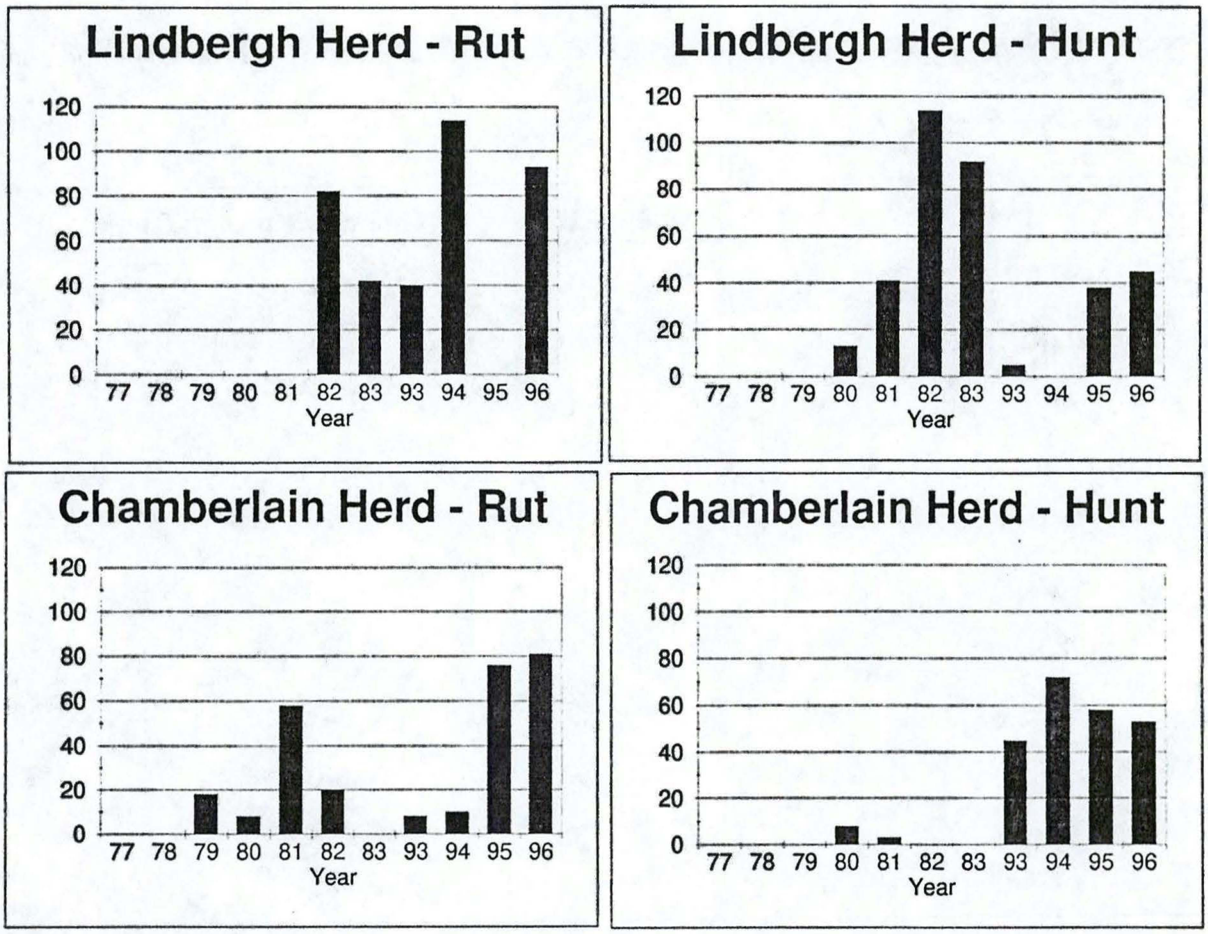

Figure 5. Highest numbers of elk counted at one time, from aerial telemetry flights, on the GR (Lindbergh herd) and NBR (Chamberlain herd) during the rut and hunting season.

Table 1. High counts of elk within private land refuge. "0" indicates no radio-collared elk occurred on private land refuge, "?" indicates elk occurred on private land refuge but no count was possible.

	Lind - Rut	Lind - Hunt	Chamb - Rut	Chamb - Hunt
1977	0	0	0	0
1978	0	0	0	0
1979	0	0	18	?
1980	0	13	8	8
1981	0	41	58	3
1982	82	114	20	0
1983	42	92	0	0
1993	40	5	8	45
1994	114	?	10	72
1995	?	38	76	58
1996	93	45	81	53

DISCUSSION

We documented increased use of private land refuges in both elk herds we studied. Elk use of private land in the study area has continued and increased since it was first observed (Edge et al. 1984). Up to 100% of the Lindbergh herd now uses the GR, accounting for as much as 71% of rut locations and 55% of hunting season locations (Table 2). Up to 75% of the Chamberlain elk herd now uses the NBR, representing as much as 37% of seasonal locations for that herd. Furthermore, use of private lands now occurs during the calving and summer seasons by the Lindbergh herd, and summer use may be starting within the Chamberlain herd. Increased use of private lands by elk and deer has occurred in numerous areas throughout the west, and leads to complex social, ethical, and biological problems (Thompson and Henderson 1998). The increased use of private property by elk is accompanied by several problems, including forage depredation, fence damage, and loss of hunter opportunity (Edge et al. 1984) . Additionally, elk use of private land refuges increases the likelihood of unethical or illegal behavior such as trespass or poaching. During both periods of this study, several instances of illegal elk harvest and unethical hunter behavior were documented, largely because elk were in clear view of Montana Highway 200 during the hunting season.

Several factors probably contribute to the use of private land refuges including behavioral responses of elk to hunting pressure, increasing elk populations, and availability of high quality forage. We suggest that elk response to hunting pressure was the dominant factor that led to the development of the private land refuges observed in our studies. Studies of elk behavior suggests that elk may be repeatedly disturbed during the hunting season, and each disturbance results in elk moving to alternative security areas until they are no longer disturbed (Lyon and

Canfield 1991, Bryant et al. 1991). Under most conditions security areas used by elk are large patches of continuous cover that are isolated from open roads (Hillis et al. 1991). However, any area with a low likelihood of hunters encountering elk may shelter elk for extended periods during the hunting season, regardless of the habitat conditions (cover and road density). The elk use of the GR clearly developed as this type of response to hunting pressure. Although the elk herd using the NBR first began to use the area during the rut, use of this refuge became most pronounced during hunting season of the second study.

Elk use of private land refuges may occur in response to hunting pressure even though traditional types of security habitat is available. Both elk herds in our study have several large contiguous blocks of cover isolated from open roads within their herd ranges. Hunters may preferentially hunt these security areas, moving elk until they encounter the private land refuges without hunting pressure. Thus, the private land refuges may become preferred security areas during the hunting season and lead to successively less use of traditional forms of security habitat.

Some of the use of private property may have resulted from an increasing and expanding elk population. However, both herd home ranges during the second study, were similar in size to herd ranges during the first study, therefore, neither herd appears to have substantially expanded its range. Percentages of radio-collared elk using refuge areas and the percentage of seasonal locations within refuge have increased, suggesting a behavioral trend shared by an increasing proportion of each herd, rather than a result of population growth.

The availability of high quality forage is another factor that may have contributed to the use of private land refuges during our study. Both areas contain irrigated hay pastures with

excellent forage. However, during the periods in which elk in both herd first began using the refuges, the forage on the hayfields had already cured and was not as high in quality as during the summer and parturition seasons. Thus, forage quality alone is not likely to have resulted in elk beginning to use the private land refuges, but it is likely that forage quality contributed to elk use expanding to earlier seasons in later years.

MANAGEMENT IMPLICATIONS

Elk use of private land refuges may result in a number of problems including forage depredation and fence damage, as well as the loss of hunting opportunity and increased illegal activity. Once elk begin to use private land refuges, our study suggests that the number of elk using these areas will increase over time, and the amount of time elk use these sites will also increase, including other seasons. Because elk have a high degree of home range fidelity (Edge et al. 1985) elk use of these refuge areas may eventually expand to year-round use. The likelihood of management problems increases with the amount and duration of use. Thus, it becomes important for wildlife and land managers to take aggressive action to reduce use of these areas. During our study, hazing, herding and special hunting seasons were used to reduce elk use of the refuges; only hunting was effective.

Special hunting seasons held on the GR resulted in temporary reductions in elk use of the area. From 30 August 1993 through 31 October 1993, 5 hunters/week were allowed to hunt antlerless elk within the GR. This coincided primarily with the rut, and ended shortly after the start of the general hunting season. Although only 1 Lindbergh elk was radio-collared in 1993 only 29% of rut locations that year were within refuge in contrast to 75% of locations during

hunting season, after the special hunt concluded. A similar relationship was noted in 1994 when, all radio-collared elk used the GR during the rut, representing 71% of radio locations for that season. A special hunt was held from 17 October through 27 November 1994, starting a week before and running through the general hunting season. During the general hunting season, 83% of radio-collared elk used the refuge but only 20% of that seasons locations were found there. General hunting season pressure, even as light as 5 hunters/week, was an effective tool for reducing both the number of elk, and duration of stay, on this refuge with very little security cover.

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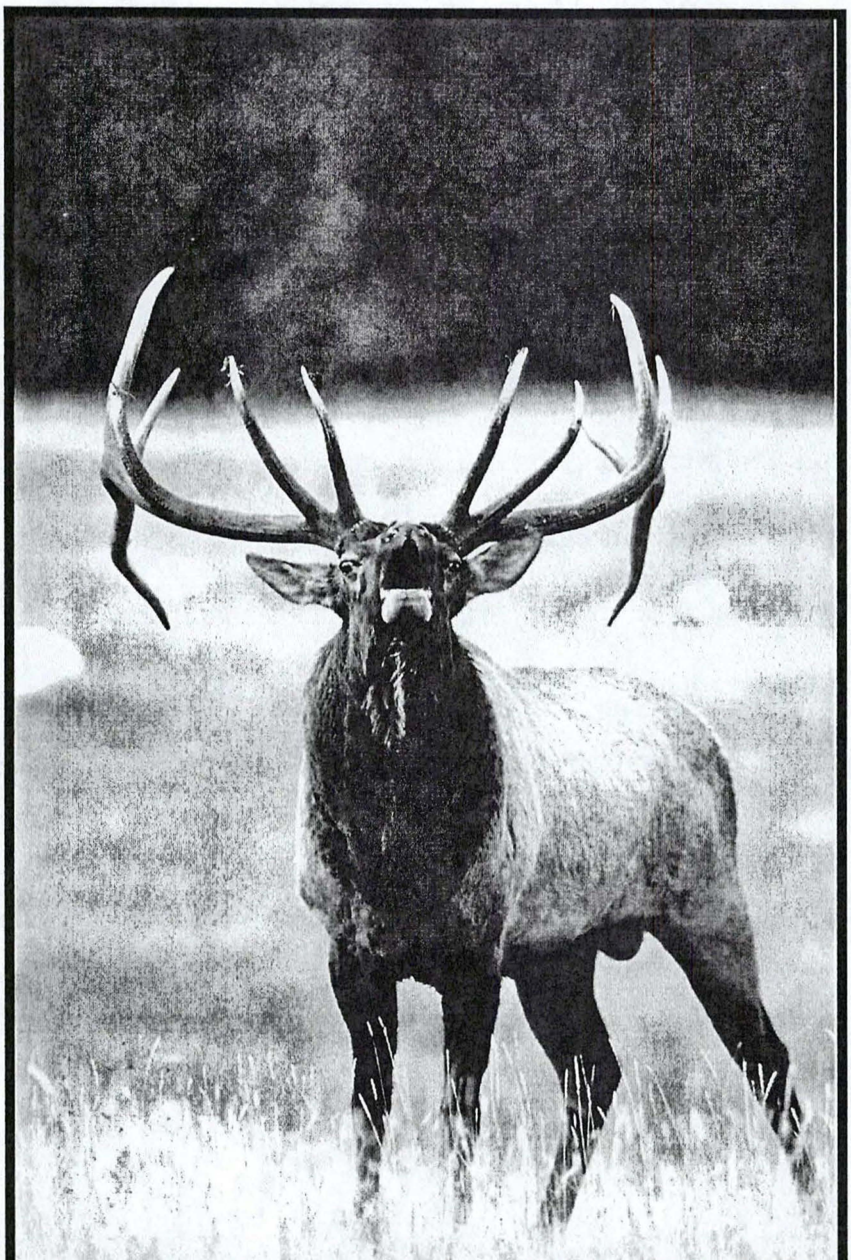
Chapter 9

OVERVIEW AND MANAGEMENT RECOMMENDATIONS



OVERVIEW AND MANAGEMENT RECOMMENDATIONS

When it was initiated, the 1993-1996 replication of the Chamberlain Creek Elk-Logging Study (1977-1983), was intended to provide evaluation of the long-term response of free-ranging elk to substantial changes in the habitat available to them. As the new study developed, and particularly as we started recognizing some of the interaction variables affecting elk behavior, our interpretations and analyses necessarily became more and more complex. The most basic change recorded in this study was evidenced in the appearance that herd home ranges for both the Chamberlain and Lindbergh had shifted very substantially.

Examination of the original data, however, suggests that the real changes in elk distribution were far less dramatic than implied by the kernal home range isopleths. Some elk from the Lindbergh herd were using a private land refuge area before 1984, but at that time it appeared this was a temporary situation related to reduced cattle grazing associated with the impending sale of the ranch. In the more recent study, this refuge area received substantially increased use, influencing the shape of the 95% isopleth to include areas previously unused by the Lindbergh herd. The appearance of the raw data point locations confirms a shift in elk use to this refuge and surrounding areas, but there is little evidence that large areas of the old home range were abandoned or new areas colonized. The distribution of location points for the Chamberlain herd provides even less evidence that the current elk are not using the area described in the earlier study. In the Chamberlain herd, concentrations of use have shifted around within the originally described area.

In confirmation of this interpretation, the examination of old and new elk locations at

landscape scale revealed increasing correlations between old and new locations at greater scales. While grid cells as small as 500 m were favored or abandoned almost randomly within both herds, elk fidelity to 2000 m cells remained low for the Lindbergh herd but was fairly high for the Chamberlain herd.

Our initial hypothesis assumed we would detect correlations between patterns of elk use and modifications of forest habitats. This hypothesis was confirmed, but the major influence of private land refuge areas -- which were located completely outside the managed forest habitats of primary interest, was unexpected. After discounting for this somewhat overriding influence, we were able to examine changes in herd distributions within different landscape scales and examine habitat selections by individual elk. Throughout these analyses, the influence of forest roads was repeatedly identified as the number one negative influence on elk habitat use.

Roads had a greater influence on elk distributions than did vegetation changes. Roads open to vehicle traffic were avoided by elk in all seasons, open roads negatively influenced elk habitat selections, and elk security was reduced by any open road. However, there was no significant change in the number of open roads over the course of this study, and our analyses all suggest there was a slight increase in elk tolerance for such roads.

Closed roads were far less significant in determining elk distribution patterns and habitat use, but these roads did prove to be important in other ways. We detected a negative relationship between elk distributions and increased densities of closed roads. This we interpreted as evidence that even minimal administrative traffic on closed roads reinforces negative behavior patterns by elk. Seasonally, roads proved to be especially important in limiting elk security during the hunting season. Almost half of the elk killed in this study were within 1000 m of an

open road even though average locations of live elk were another 1000 m distant. Security created by distance is much reduced, however, where closed roads can be used by hunters to facilitate access to areas distant from trailheads.

The importance of closed canopy (>30 % crown closure) coniferous forest on summer range appeared to have declined by almost half as elk selected increasingly fragmented habitats during the summer. During the hunting season, however, closed canopy forest correlated positively with elk numbers at all landscape scales, and elk habitat selections confirmed the importance of larger forested patches in providing security.

Conversely, the open coniferous forest was an increasingly important component of habitat selections except during the rut and hunting seasons. Vulnerability in this type is indicated by the generally negative correlation with elk numbers during the hunting season at all landscape scales. However, hunters preferred the more open forest because of better visibility, and although only 4 percent of hunting season elk locations were recorded in open coniferous forest, 17 percent of the elk killed were in this type.

Management of forested habitats for elk presents a wide variety of challenges, but two of the management problems demonstrated by this study have the potential to be overwhelming. The distributional shift of the Lindbergh herd to refuge on private land has effectively removed this herd from any meaningful action by either the game managers or the public land managers. A smaller, but significant, portion of the Chamberlain herd have also discovered refuge on private land. At first, the refuge situation was simply a question of location during the hunting season, with the elk moving back to forested habitats for the remainder of the year. Today, these elk are becoming habituated to the ranch environment and irrigated hayfields. This has not only

removed the elk from the public domain, it has on several occasions created problems for ranchers and law enforcement personnel and severely tested the ethical standards usually considered acceptable in sport hunting.

Recommendation: Wildlife professionals, landowners and hunters should attempt to find a workable resolution to the problem of the increased elk use of refuges on private land. We are aware of situations in which landowners have been encouraged to participate with state game departments in the cooperative management of hunters, use of cattle grazing to discourage elk use, and of hazing attempts. The application of persistent, low intensity hunting pressure, through a cooperative agreement between a private landowner and MDFWP, appeared to be successful in reducing overall elk use on a ranch with little forest cover. We are not aware, however, that any of these methods have been properly analyzed.

The second problem is more tractable, but no less important. In every habitat relationship examined in this study, and in every season, the influences of roads proved to be more important than any other variable of the elk environment. Open roads, in particular, may preclude elk use of large areas of otherwise acceptable habitat. Even sporadic administrative traffic on closed roads can reinforce this avoidance behavior by elk. And, during the hunting season, closed roads can be expected to provide travel routes that significantly increase elk vulnerability.

Recommendation: In managing forests to enhance elk habitats, any road closure is probably beneficial, but area closures appear to be more effective than blockage of individual roads. Where area closure is also intended to reduce elk vulnerability, security can be increased by maintaining large forest cover patches distant from access points and by actions designed to keep hunter densities below 0.5 hunters/km^2 in a third of the area open to hunting. Some considerations that could be used to reduce hunter density might include random physical barriers on closed roads, restrictions on overnight camps, and restrictions on the use of bicycles and horses.

Chapter 10

APPENDIX

Appendix A

Table A.1. Capture and relocation data for the Chamberlain Creek Elk Study, 1993-1996.

ELK#	FREQ	EAR1	EAR2	CAPDATE	METHOD	SEX	AGE	#LOC	FATE
1	151.524	32501	32502	930121	CL	F	5.5	0	D
2	152.858	32537	32538	930129	CL	F	5.5	110	K
3	151.190	32549	32550	930204	CL	F	7.5	0	D
4	152.478	32551	32552	930205	CL	M	0.5	24	K
5	150.053	32559	32560	930206	CL	F	7.5	118	K
7	152.032	32574	32575	930213	CL	F	3.5	75	?
8	151.829	32563	32564	930207	CL	F	4.5	26	D
9	150.199	30911	30912	930220	CL	F	3.5	121	A
10	150.241	30923	30924	930222	CL	M	0.5	0	D
11	152.053	30926	30927	930222	CL	F	2.5	116	A
12	152.355	30933	30934	930615	CL	F	3	54	K
13	150.282	30953	30955	930616	CL	M	1	25	K
14	151.658	30956	30957	930616	CL	F	7	16	D
15	150.652	30935	30936	930617	CL	M	1	19	K
-	-	30958	30959	930624	CL	M	0	0	-
16	151.793	30941	30942	930707	CL	M	2	83	K
17	152.304	30968	-	930707	CL	M	2	53	M
18	152.960	30971	30972	930708	CL	M	1	24	C
19	152.759	30947	30948	930714	CL	M	2	15	K
20	151.753	30973	30974	930715	CL	F	1	119	A
21	152.798	30976	30977	930716	CL	M	2	46	K
22	152.329	30980		930721	CL	F	3	18	D
23	152.740	23040	23041	931210	NG	F	4.5	20	K
24	-	-	-	931210	NG	F	-	0	M
25	152.780	23044	23045	931210	NG	F	3.5	27	C
26	152.897	23028	23029	931210	NG	F	4.5	83	A
27	150.312	23032	23033	931210	NG	F	3.5	92	A
28	152.129	23038	23039	931210	NG	F	8.5	62	C
29	151.700	23026	23027	931210	NG	F	6.5	97	A
30	152.602	23042	23043	931210	NG	F	4.5	31	D

ELK# = elk identification number; **FREQ** = elk radio frequency; **EAR1** and **EAR2** = eartag numbers; **CAPDATE** = capture date (YYMMDD); **METHOD** = capture method (CL = Clover trap, NG = netgun); **SEX** = sex (F = female, M = male), **AGE** = elk age at capture; **#LOC** = number of elk radio relocations during study; **FATE** = eventual fate of elk (M = capture mortality, K = killed by hunter, D = died, probably other than hunter kill, C = collar failed, A = alive at end of study, ? = unknown)

Appendix A (cont.)

Table A.1 (cont.)

ELK#	FREQ	EAR1	EAR2	CAPDATE	METHOD	SEX	AGE	#LOC	FATE
31	152.940	23036	23037	931210	NG	F	2.5	31	K
32	150.454	23030	23031	931210	NG	F	0.5	40	C
33	152.154	23005	23006	931211	NG	F	0.5	2	D
34	150.162	23001	23002	931211	NG	M	2.5	27	K
35	-	23046	23047	931211	NG	F	0.5	0	-
36	152.405	23051	23052	931211	NG	M	1.5	56	K
37	152.204	23057	23058	931211	NG	M	1.5	10	K
38	151.969	23034	23035	931211	NG	M	0.5	26	K
39	-	-	-	940309	NG	F	8.5	0	M
40	-	-	-	940309	NG	M	1.5	0	M
41	152.503	30859	30988	940309	NG	F	3.5	50	D
42	150.120	30987	30891	940309	NG	M	0.5	25	K
43	151.321	26483	30813	940309	NG	M	1.5	0	D
44	152.544	26450	30815	940309	NG	F	1.5	9	?
45	150.011	30811	30899	940309	NG	F	3.5	95	A
46	152.759	30812	30886	940309	NG	M	0.5	3	C
47	150.134	30881	30884	940309	NG	M	0.5	26	K
48	152.239	34006	34007	950306	NG	F	3.5	17	C
49	152.921	34197	34199	950306	NG	M	0.5	0	D
50	150.120	34195	34196	950306	NG	M	2.5	45	K
51	152.354	34010	34011	950306	NG	F	3.5	66	A
52	152.817	34002	34003	950306	NG	M	1.5	22	K
53	152.478	34008	34009	950306	NG	F	3.5	66	A
54	151.321	34013	34200	950306	NG	M	1.5	0	D
55	152.255	34192	34193	950306	NG	M	1.5	22	?
56	150.134	34043	34044	950306	NG	M	1.5	24	K
57	150.241	34047	34048	950306	NG	F	1.5	3	?
58	152.154	34045	34046	950306	NG	F	2.5	11	C
59	152.740	34049	34050	950306	NG	F	3.5	65	A
60	-	34190	34191	950306	NG	F	1.5	0	-

ELK# = elk identification number; **FREQ** = elk radio frequency; **EAR1** and **EAR2** = eartag numbers; **CAPDATE** = capture date (YYMMDD); **METHOD** = capture method (CL = Clover trap, NG = netgun); **SEX** = sex (F = female, M = male), **AGE** = elk age at capture; **#LOC** = number of elk radio relocations during study; **FATE** = eventual fate of elk (M = capture mortality, K = killed by hunter, D = died, probably other than hunter kill, C = collar failed, A = alive at end of study, ? = unknown)

Appendix A (cont.)

Table A.1 (cont.)

ELK#	FREQ	EAR1	EAR2	CAPDATE	METHOD	SEX	AGE	#LOC	FATE
61	-	34194	34198	950309	NG	M	1.5	0	-
62	152.377	34182	34183	950309	NG	M	2.5	45	A
16	152.563	30941	30942	950309	NG	M	3.5	0	K
17	-	-	-	950309	NG	M	3.5	0	M
63	151.658	34005	34188	950621	CL	F	2	52	K
64	152.940	34026	34027	950624	CL	F	1	60	A
65	151.829	34028	34029	950625	CL	F	1	55	A
66	152.154	35522	35523	960318	NG	F	3.5	31	A
67	152.799	35520	35521	960318	NG	F	3.5	33	A
68	151.969	35516	35517	960318	NG	F	1.5	33	A
69	152.921	35524	35525	960318	NG	M	2.5	26	?
70	152.602	35504	35505	960318	NG	M	1.5	25	K
71	150.807	35502	35503	960318	NG	M	1.5	19	A
72	151.025	35506	35507	960318	NG	F	4.5	32	A
73	150.170	35518	35519	960318	NG	F	1.5	32	A
74	152.564	35508	35509	960318	NG	M	0.5	31	A
75	152.780	35526	35527	960319	NG	F	3.5	33	A
32	150.609	23030	23031	960319	NG	F	3.5	0	A
76	150.455	35549	35550	960319	NG	F	5.5	32	A
77	150.135	35545	35546	960319	NG	M	0.5	33	A
78	152.206	35510	35511	960319	NG	M	0.5	24	A
79	151.321	35543	35544	960319	NG	M	0.5	3	D
80	150.258	35541	35542	960319	NG	M	0.5	33	A
81	152.304	35512	35513	960319	NG	M	1.5	29	A
82	152.406	35547	35548	960319	NG	M	1.5	12	?
83	-	-	-	960319	NG	F	5.5	0	M

ELK# = elk identification number; **FREQ** = elk radio frequency; **EAR1** and **EAR2** = eartag numbers; **CAPDATE** = capture date (YYMMDD); **METHOD** = capture method (CL = Clover trap, NG = netgun); **SEX** = sex (F = female, M = male), **AGE** = elk age at capture; **#LOC** = number of elk radio relocations during study; **FATE** = eventual fate of elk (M = capture mortality, K = killed by hunter, D = died, probably other than hunter kill, C = collar failed, A = alive at end of study, ? = unknown)

Appendix B

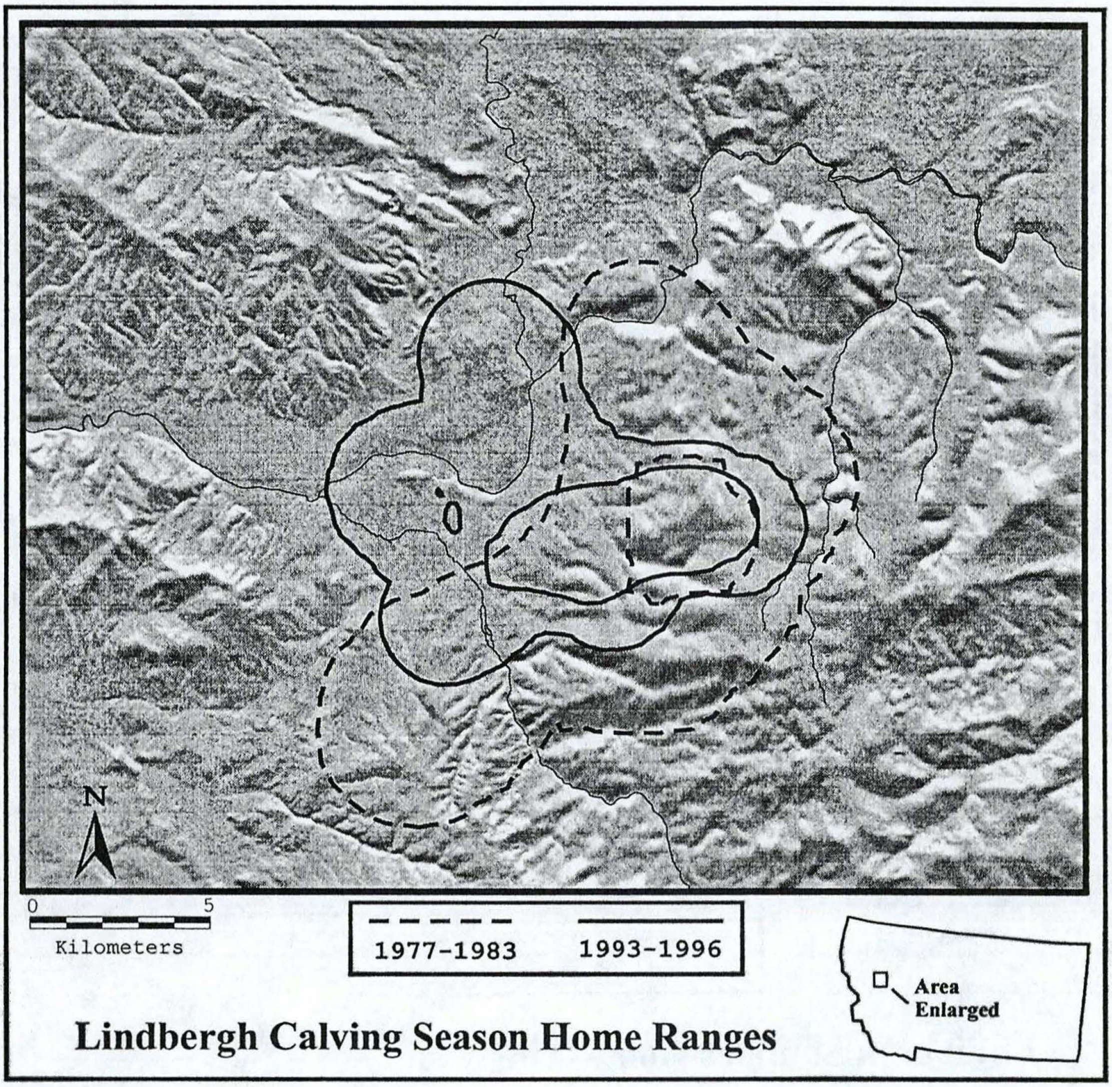


Figure B.1 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Lindbergh calving season home ranges.

Appendix B (cont.)

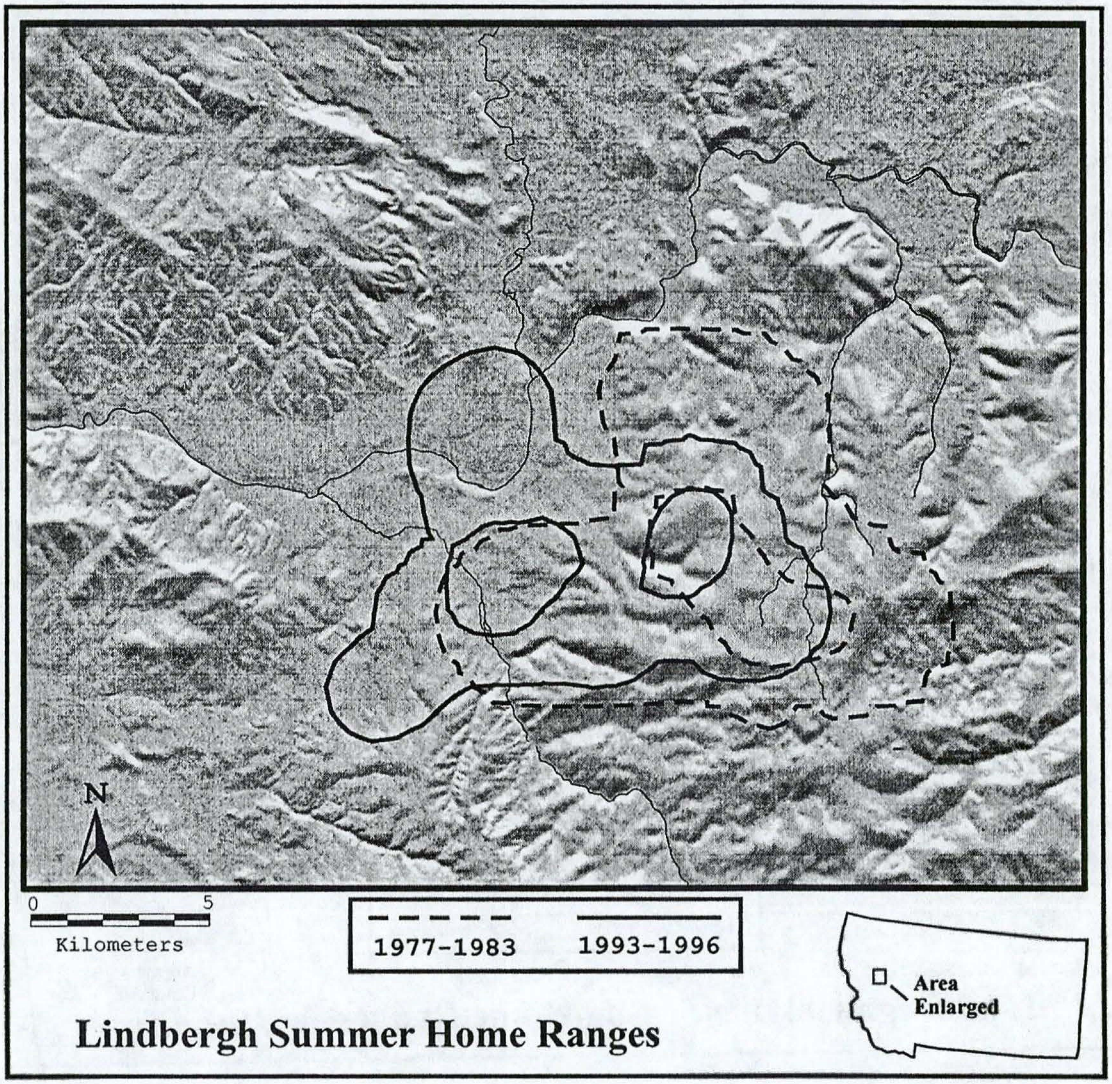


Figure B.2 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Lindbergh summer home ranges.

Appendix B (cont.)

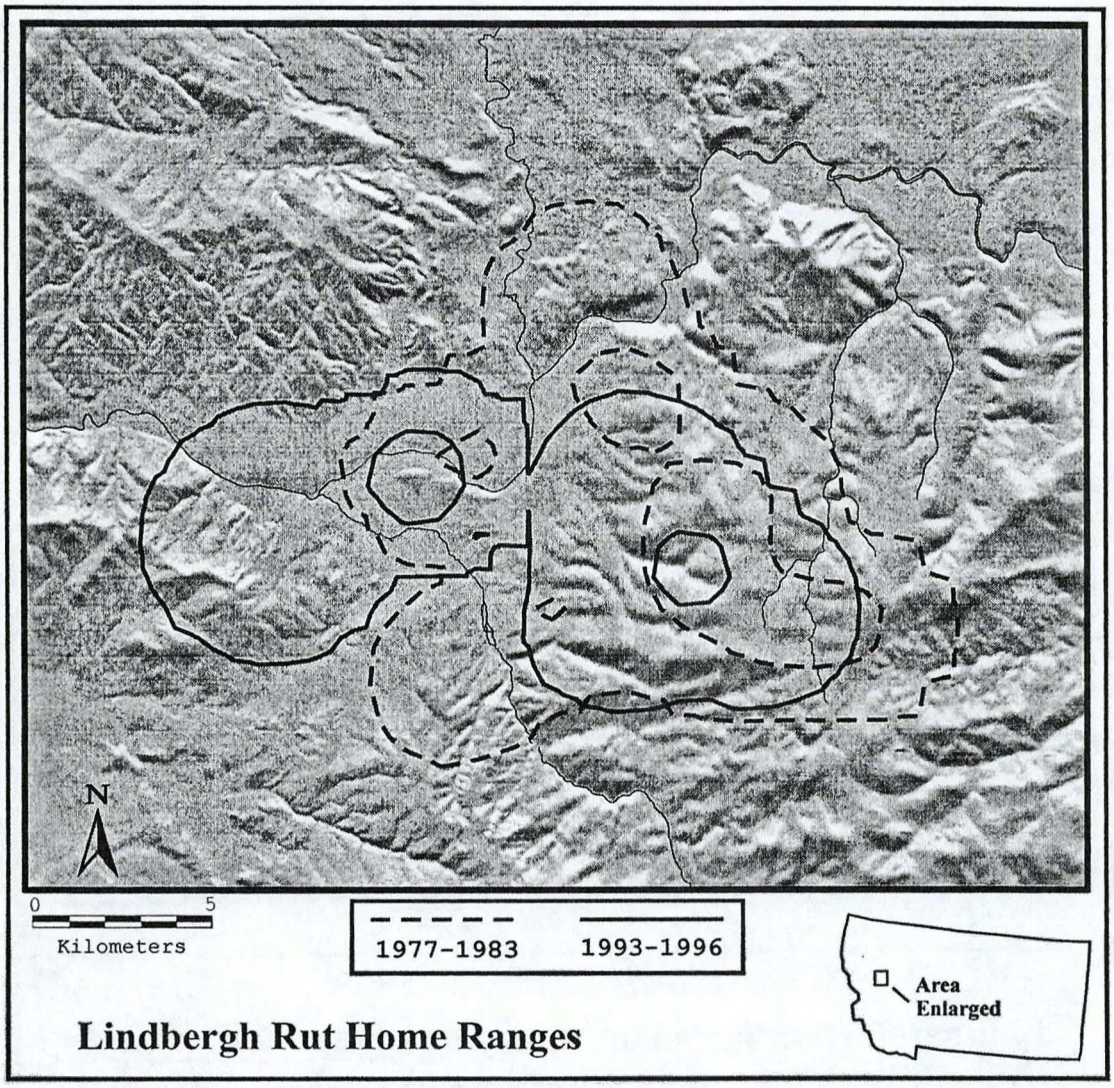


Figure B.3 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Lindbergh rut home ranges.

Appendix B (cont.)

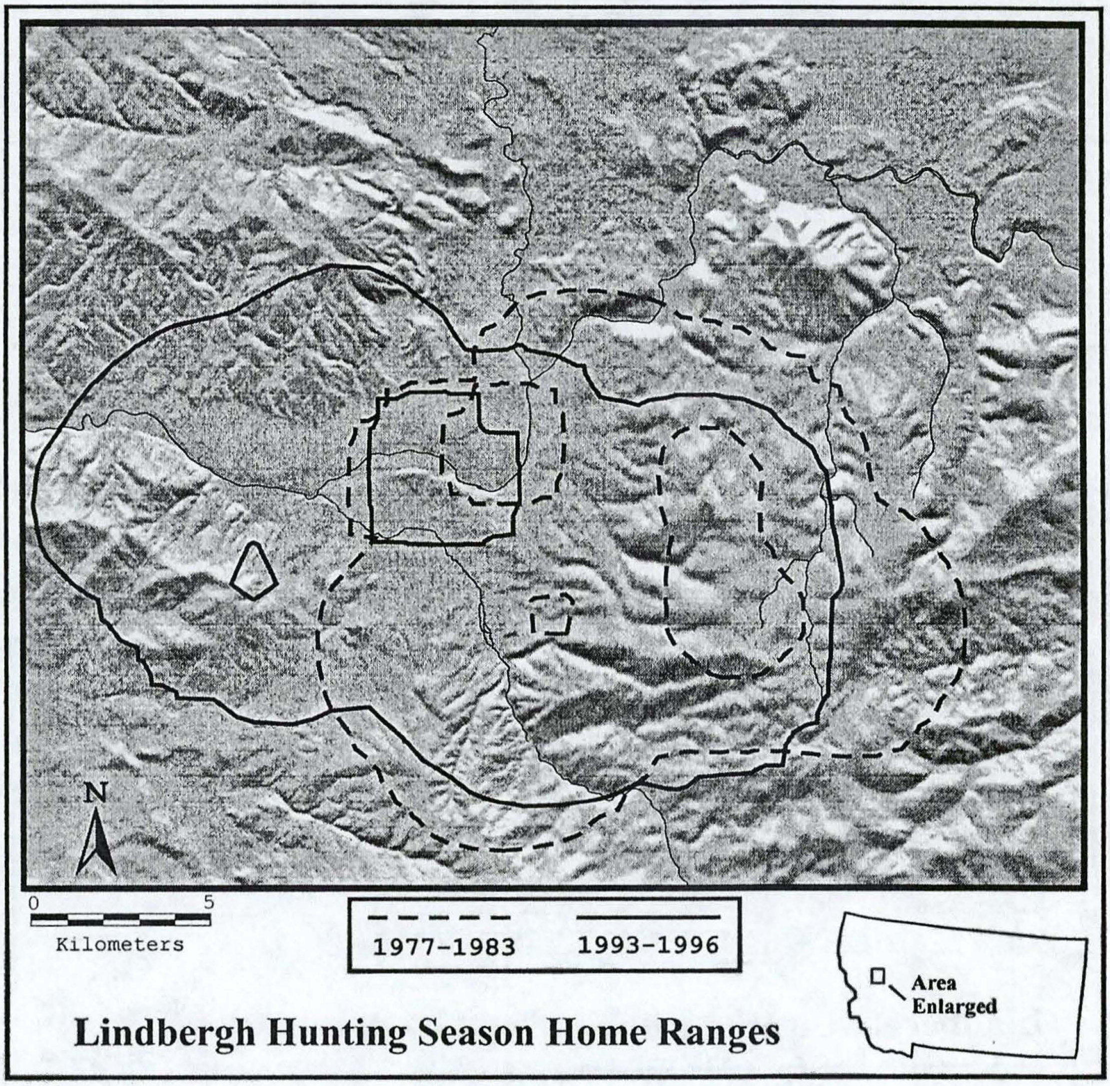


Figure B.4 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Lindbergh hunting season home ranges.

Appendix B (cont.)

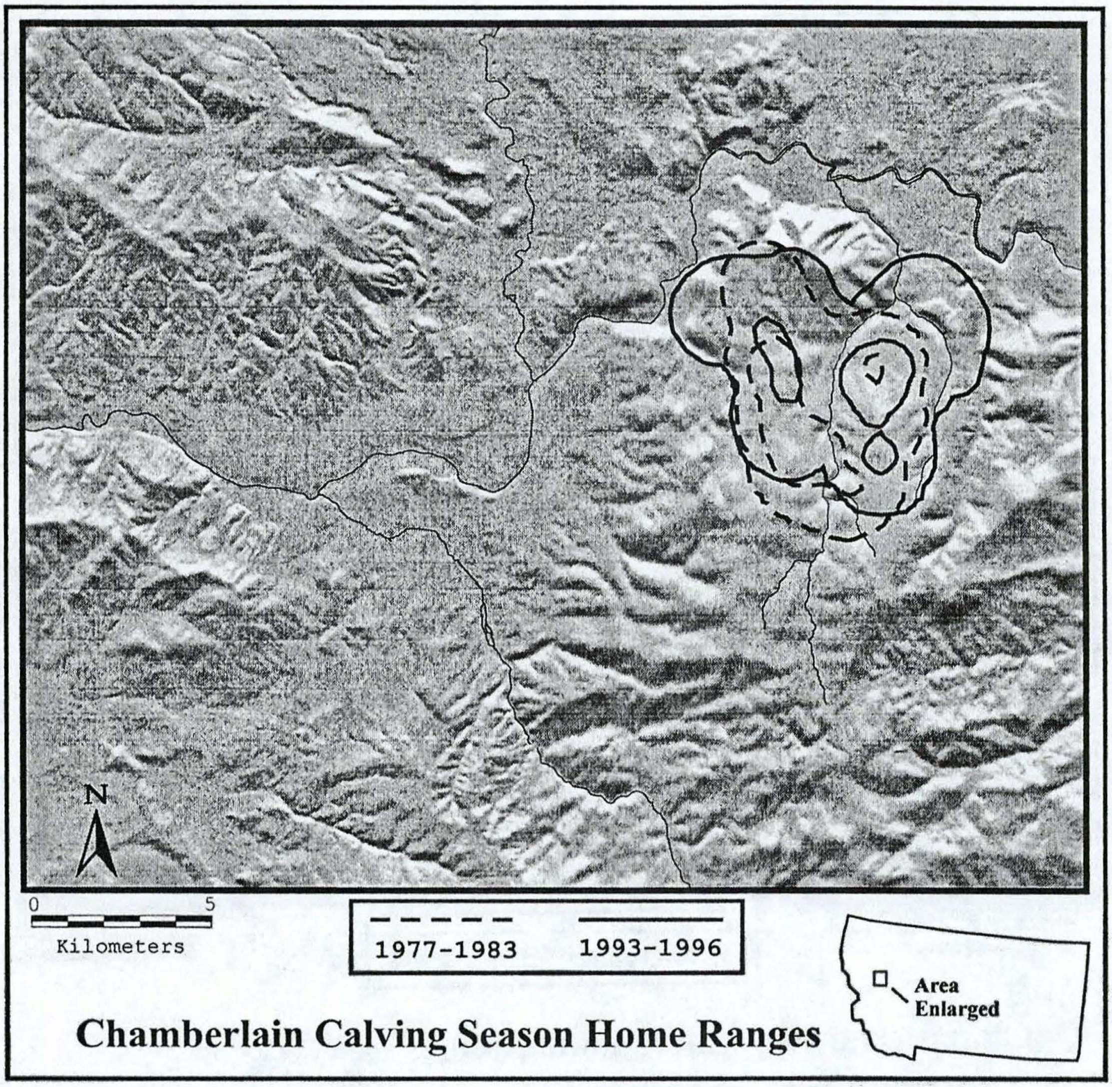


Figure B.5 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Chamberlain calving season home ranges.

Appendix B (cont.)

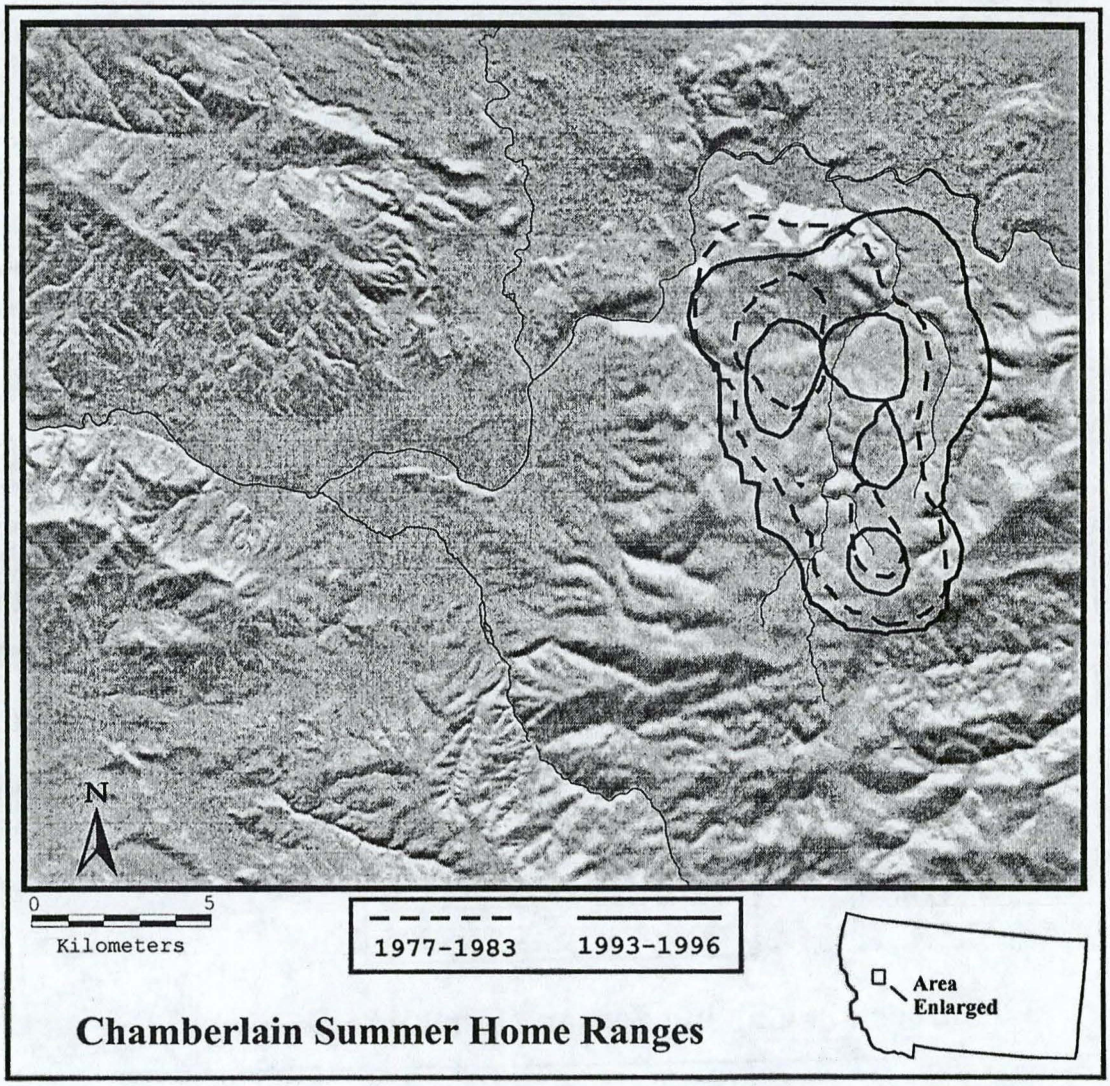


Figure B.6 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Chamberlain summer home ranges.

Appendix B (cont.)

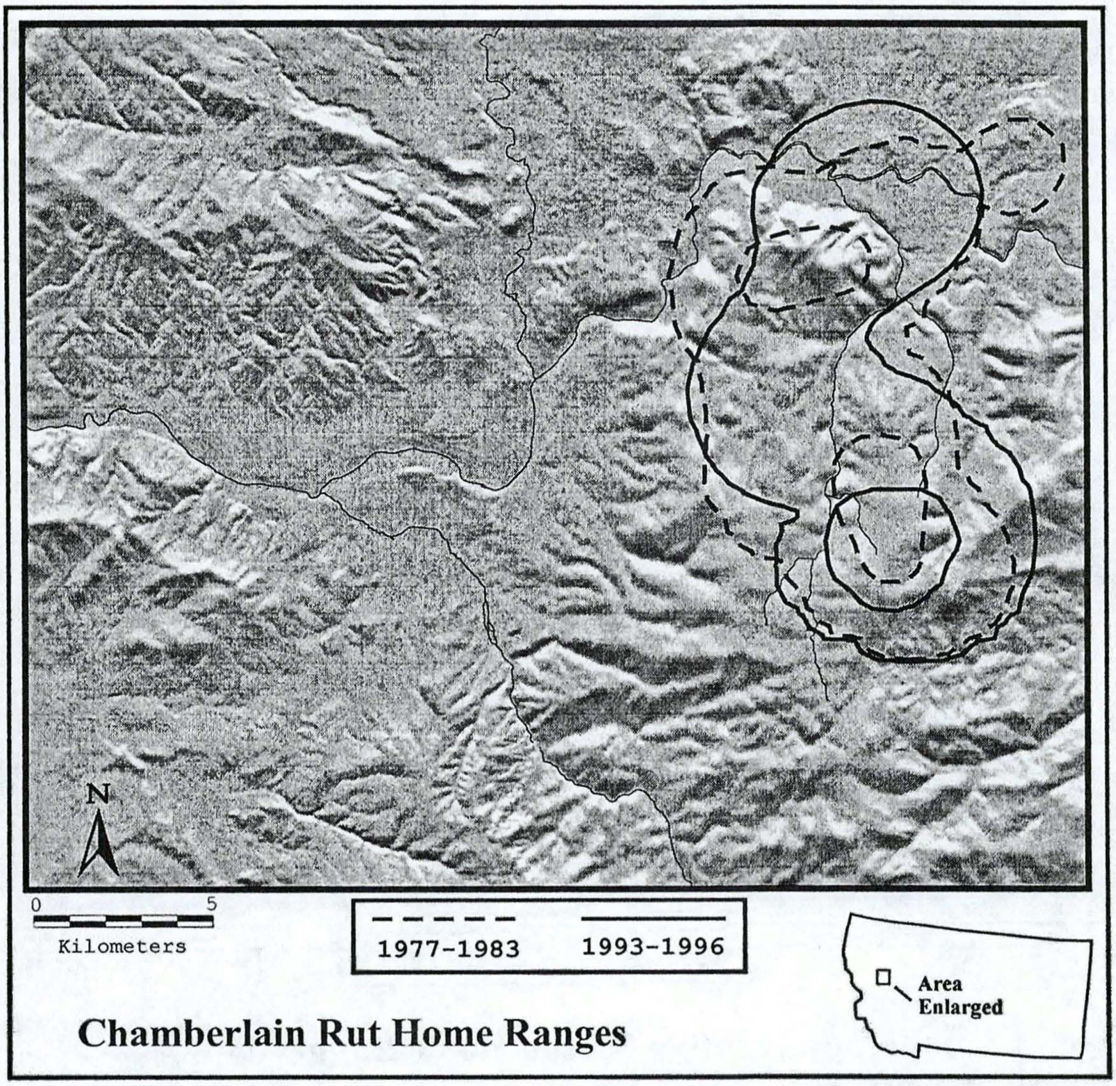


Figure B.7 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Chamberlain rut home ranges.

Appendix B (cont.)

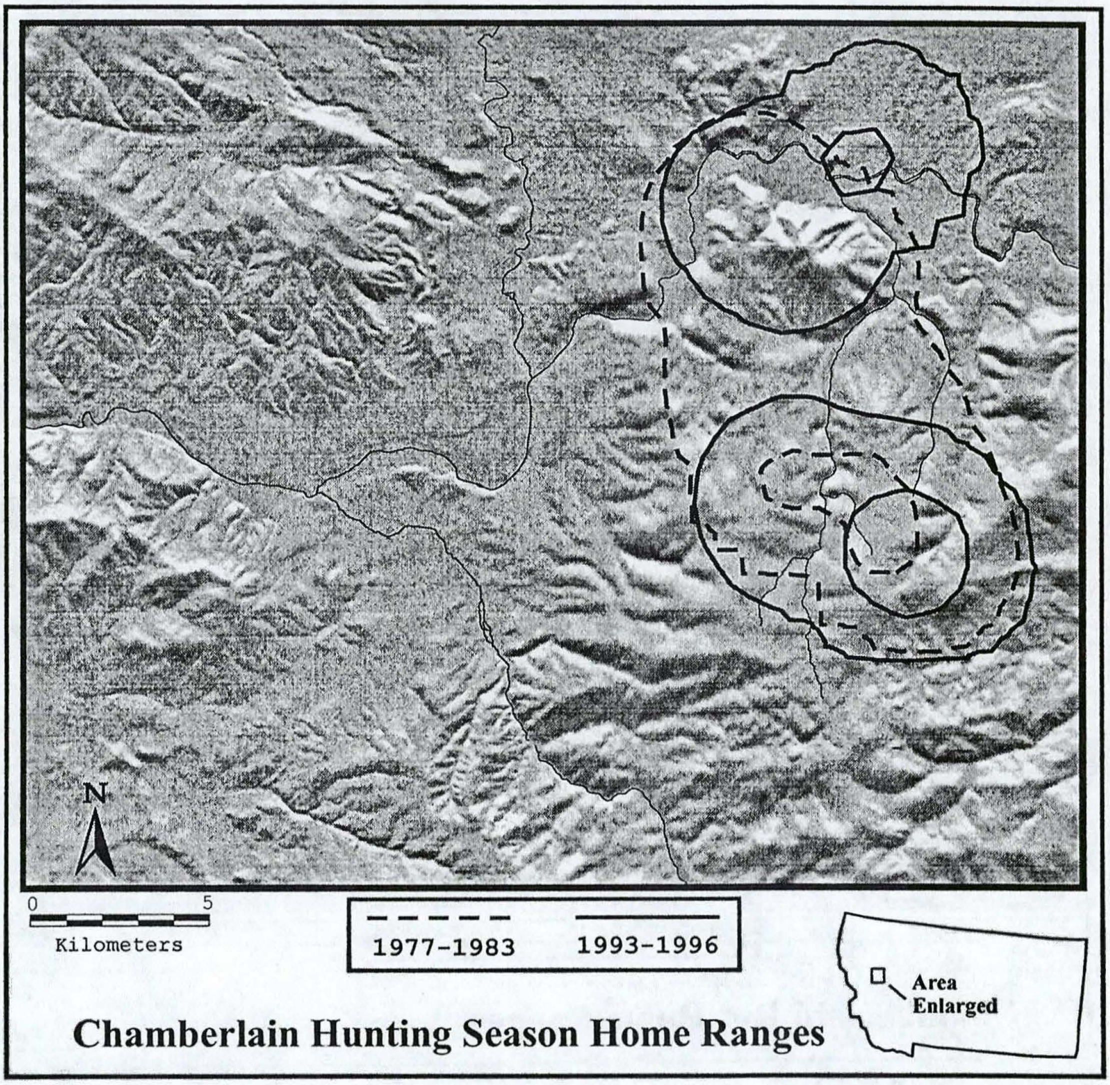


Figure B.8 Adaptive kernal 95% (exterior) and 50% (interior) isopleths, for old and new Chamberlain hunting season home ranges.

Appendix C

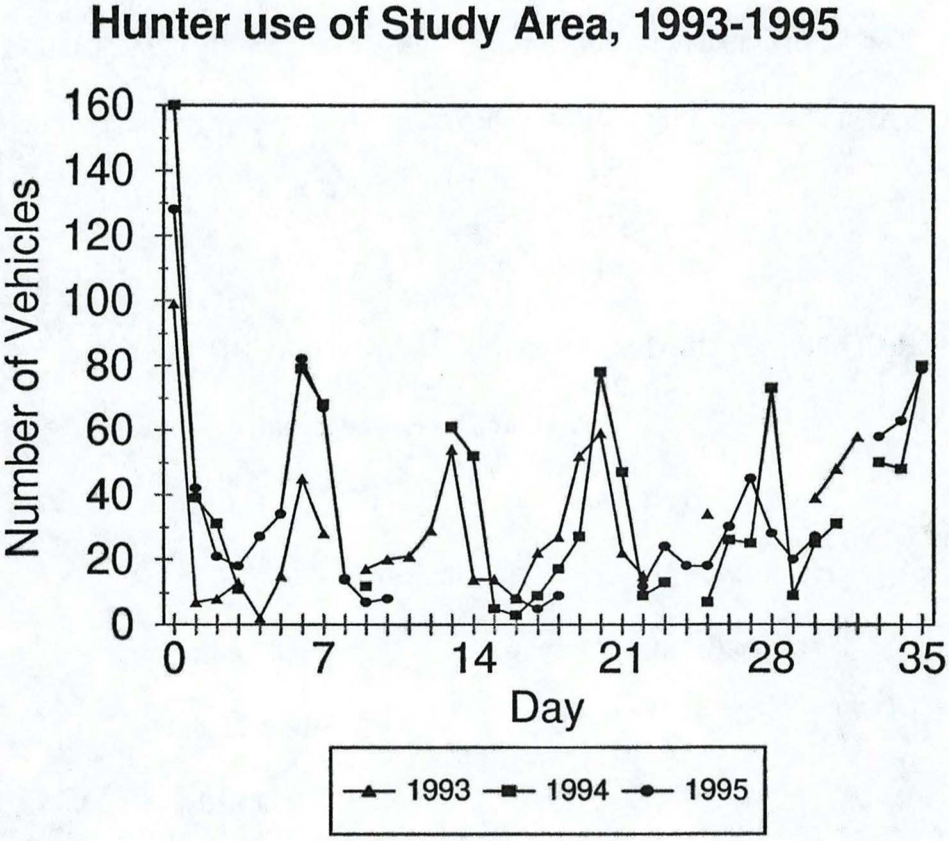


Figure C.1. Hunter use of the Blackfoot Special Management Walk-in Area, as indicated by vehicles counted at trailheads during the general hunting season, 1993-1995.

APPENDIX D

VEGETATION CLASSIFICATION SYSTEM

The following classification system was used to identify the vegetation present in each polygon of the existing vegetation coverage. All cover percentages refer to canopy coverage.

COVER CODE	CLASS	DESCRIPTION
	Urban or Developed Land	
1500	Urban/ Industrial	
	Agriculture	
2101	Cropland/ Pasture	Small grains
		Fallow lands
		Shelter belts
2102	Irrigated Crops	Row crops
		Alfalfa
		Hay
2103	Rangelands	Crested wheatgrass
		Russian wildrye
		other dry-land pastures

Appendix D (cont.)

COVER CODE	CLASS	DESCRIPTION
	Non-Forested Land	<15% forested
	Grasslands	<15% shrubs
3101	Foothills/ Parklands	Bluebunch wheatgrass
		Blue grama
		Idaho Fescue
		Lupine
		Shrubby cinquefoil
3102	Disturbed grasslands	Cheatgrass
		Japanese Brome
		Knapweed
3103	Other herbaceous	Clearcut with beargrass
		Fireweed
	Shrublands	≥30% shrubs
3201	Mesic upland shrub	Rocky Mountain Maple
		Serviceberry
		Western snowberry
		Ninebark
		Chokecherry
		Ceanothus
		Huckleberry

Appendix D (cont.)

COVER CODE	CLASS	DESCRIPTION
3202	Xeric upland shrub	Raspberry,
		Rose
		Mountain Mahogany
3206	Sagebrush	Mountain big sagebrush
		Bluebunch wheatgrass
	Mixed Grass & Shrubland	≥15% and <30% shrub
3301	Mixed Grass/ Shrub	Bitterbrush-grassland
		Sagebrush-grassland
3302	Other shrub	
	Forest Land	
4101	Broadleaf forest	>30% broadleaf and
		<30% conifers.
		Non-riparian areas.
	Coniferous forests	<30% broadleaf and >30% conifers.
4201	Spruce forest	Picea englemannii
4202	Lodgepole Pine forest	Pinus contorta

Appendix D (cont.)

COVER CODE	CLASS	DESCRIPTION
4205	Ponderosa Pine forest	Pinus ponderosa
4211	Douglas fir forest	Pseudotsuga menzesii
4214	Western Larch forest	Larix occidentalis
4217	Mixed Coniferous forest	>2 spp., each with 15-30% total cover.
4250	Open Douglas fir	Douglas fir with a low canopy cover. Open park.
4260	Regenerating clearcut	A clearcut with a high percentage of tall (>8 ft.) regenerating trees.
	Water	
5200	Lakes	
	Riparian & Wetland Areas	Adjacent to surface water.
6201	Wet Meadows	Wet-moist meadow

Appendix E

Table E.1. Percentage of radio-collared elk and telemetry locations within private land refuges by refuge, season and year for the Chamberlain Creek elk study, 1977-83 and 1993-96.

Refuge/season		1977	1978	1979	1980	1981	1982	1983	1993	1994	1995	1996
Greenough Refuge												
Parturition	Radios	0(5)[a]	0(8)	0(8)	0(9)	0(9)	0(13)	0(11)	0(1)	33(6)	63(8)	63(8)
	Locations	0(9)[b]	0(15)	0(21)	0(24)	0(27)	0(47)	0(42)	0(1)	12(17)	39(23)	51(39)
Summer	Radios	0(5)	0(8)	0(8)	0(9)	0(9)	0(13)	0(11)	100(1)	33(6)	38(8)	88(8)
	Locations	0(30)	0(87)	0(100)	0(84)	0(51)	0(87)	0(97)	64(11)	4(68)	7(81)	26(87)
Rut	Radios	0(5)	0(8)	0(8)	0(9)	0(9)	77(13)	82(11)	100(1)	100(6)	50(8)	100(8)
	Locations	0(40)	0(67)	0(55)	0(56)	0(46)	35(79)	28(80)	29(7)	71(42)	7(56)	91(64)
Hunt	Radios	0(5)	0(8)	0(8)	11(9)	22(9)	77(13)	55(11)	100(1)	83(6)	88(8)	100(8)
	Locations	0(20)	0(25)	0(32)	6(33)	33(27)	51(79)	39(46)	75(8)	20(30)	53(64)	55(53)
North Blacktail Refuge												
Parturition	Radios	0(4)	0(6)	0(5)	0(9)	0(8)	0(8)	0(7)	0(8)	0(8)	0(8)	0(11)
	Locations	0(8)	0(22)	0(20)	0(22)	0(42)	0(42)	0(26)	0(2)	0(19)	0(33)	0(50)
Summer	Radios	0(4)	0(6)	0(5)	0(9)	0(8)	0(8)	0(7)	0(8)	0(8)	0(8)	36(11)
	Locations	0(24)	0(77)	0(52)	0(89)	0(111)	0(79)	0(61)	0(87)	0(83)	0(93)	4(126)
Rut	Radios	0(4)	17(6)	40(5)	33(9)	38(8)	13(8)	0(7)	13(8)	25(8)	75(8)	64(11)
	Locations	0(32)	2(42)	2(35)	14(57)	4(84)	2(49)	0(39)	4(54)	7(55)	26(54)	30(94)
Hunt	Radios	0(4)	0(6)	20(5)	11(9)	25(8)	0(8)	0(7)	13(8)	38(8)	50(8)	45(11)
	Locations	0(16)	0(24)	5(20)	2(46)	5(37)	0(28)	0(36)	11(55)	18(40)	37(59)	33(72)

[a] Percent of radio collars (total collars in herd). [b] Percent of telemetry locations (total location per season and herd).